STATUS, ECOLOGY AND CONSERVATION OF STRIPED HYENA *Hyaena hyaena* IN GIR NATIONAL PARK AND SANCTUARY, GUJARAT

SUMMARY
THESIS

SUBMITTED FOR THE AWARD OF THE DEGREE OF

Doctor of Philosophy

IN

WILDLIFE SCIENCE

BY

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EXECUTIVE SUMMARY

Introduction

The research project titled "Status, Ecology and Conservation of Striped Hyena (*Hyaena hyaena*) in Gir National Park and Sanctuary, Gujarat, India" funded by Ministry of Environment and Forest (Government of India) was started in joint collaboration of Wildlife Society of India, Aligarh and Gujarat Forest Department in April 2006. I was selected as research fellow in this project and worked as junior research fellow from August 2006 to July 2008 and as senior research fellow from August 2008 to September 2009. Data generated from this research project was utilized to prepare this thesis. The overall goal of the study was to generate information on population status and ecology of striped hyena in Gir National Park and Sanctuary (GNPS) for the formulation of a suitable management strategy for long term conservation of the target species.

Although striped hyena is big carnivore, but we still know very few about the animal ecology, social organization, and behavior etc. Very few studies have been done, and only few study publications from Africa (Kruuk 1976; Leakey et.al, 1999), Israel (Macdonald, 1978; Bouskil, 1984; Ilani, 1975; Kerbis-Peterhans and Horwitz, 1992; Skinner and Ilani, 1979), India (Davidar, 1990), and in captivity by Rieger, 1978, 1979a, 1979b are available. However, most of data are based on anecdotal information and were brief and relatively informal. Only systematic study was conducted by Wagner (2006), on behavioral ecology of striped hyena in Laikipia District, Kenya.

The ecology of the striped hyena (*Hyaena hyaena*) is little understood and has only marginally been investigated. This study was originally designed, to fill the 'gap' in our understanding the ecology of this species.

Objectives of this study

1. To investigate the current status, distribution and abundance of striped hyena in different management units and habitats of Gir National Park and Sanctuary.
2. To investigate feeding ecology of striped hyena in Gir National Park and Sanctuary.
3. To investigate the habitat use of striped hyena in Gir National Park and Sanctuary.
4. To investigate the social organization and behavior of striped hyena in Gir National Park and Sanctuary.
5. To evaluate the habitat suitability model for striped hyena in Gir National Park and Sanctuary.

Methodology

Several sets of methodology were used to fulfill these objectives.

Population estimation

Photographic capture-recapture sampling technique was used for estimating abundance of striped hyenas. A grid of 2.5 x 2.5 km^2 overlaid on the GNPS, and 15 grids in four zones, east, central, national park, and west was selected systematically to cover all the habitat types and management units for the capture-recapture sampling. The program CAPTURE was used to analyze the capture and recaptured photograph data of striped hyena.

Density estimates were generated by dividing striped hyena number by the effectively sampled area, minimum convex polygon with buffer from Half Mean Maximum Distance Moved (HMMDM).

Food habits

Scat analysis method was used to determine the food habits of striped hyena in GNPS. The scats were collected randomly from October 2006 to June 2009.

Seasonal and annual variation was also observed. To find the striped hyena food habit in different management unit of GNPS, scats collected were separated in to three zones as West Gir, Central Gir and East Gir, analyzed and represented accordingly. Also, to find any difference in striped hyena diet between different zones, chi square test was performed. Biomass of prey ingested was calculated by estimating the weight of prey eaten per scat sample for each prey type.

Habitat use

Habitat use of striped hyena was examined by determining proportion of location on the basis of direct and indirect evidences (foot print, resting sites, dens and scats) of striped hyena from all over the GNPS. Data on habitat use of lion (*Panthera leo persica*) and leopard (*Panthera pardus*) were also collected and recorded same as described for striped hyena, to see the variation of habitat use between these three big carnivores of GNPS.

The analysis of vegetation was done in GNPS. The study area was divided into four zones on the basis of vegetation and management unit namely west zone, east zone, Central zone and NP zone. Vegetation sampling was carried out on three transects of 3 km length in each sampled zone, with total 12 transects (36 km) in all over the Gir. Sampling of vegetation was done in 10m radius circular plots at each transect at an interval of 100m, with a total 31 plots on each transect, 93 plots at each sampling zone and 372 plots in total from all the four sampled zone.

Seasonal habitat use was calculated and chi square test was computed to test seasonal variation in habitat use of striped hyena and variation in habitat use between lion, leopard, and hyena in GNPS. Habitat availability and utilization by striped hyena in GNPS was assessed following Neu et al., 1974. Data was also subjected to PCA using SPSS to observe the relation between striped hyena and habitat.

Denning and behavior

Dens and resting sites were selected for the sampling and data pertaining to vegetation characteristics and den parameters were collected. Standard vegetation sampling protocol was used to analyze the vegetation. Den opening parameter and slop of terrain and direction of opening or hill slop were also recorded. GPS location and elevation was recorded using GPS receiver. All the possible measurements of den and resting sites were taken for the analysis.

Active dens were monitored regularly at dawn and dusk from a hide from an appropriate distance, which varied from place to place depending on terrain (moderate hilly to steep slope) and vegetation, using binocular and spot scope avoiding disturbance to animals. Wherever possible, behavioral activities were documented using a camera (Canon EOS 350D).

Habitat suitability modelling using remote sensing and GIS

Application of remote sensing and Geographic Information System (GIS) as a tool has assumed immense significance in habitat suitability modelling for various wildlife species. Models are now widely used in conservation ecology and wildlife management. This study evaluated habitat suitability for striped hyena (*Hyaena hyaena*) in GNPS, India. The satellite imagery and topographic maps were used to generate spatial data of different variables *viz.*, forest type, forest density, measures of proximity to disturbances (road, railways and settlements) and water. Satellite data of Landsat-TM dated 15th May 2009, path-row: 149-45 and the digital elevation model (DEM) data of shuttle radar topographic machine (SRTM) was used for the modelling. Application of binomial multiple logistic regression (BMLR) is a statistical technique for predictive modelling. Binomial logistic regression is a form of regression which is used when the dependent variable is dichotomous and independent variables are continuous. For BMLR statistical analysis, statistical package for the Social Sciences (SPSS) has been widely used. The BMLR applies maximum likelihood estimation after transforming the dependent variable into a logit variable. A digital terrain model

was used to create slope, aspect, elevation and GPS location of animal's presence were used in a "binomial multiple logistic regression" model in striped hyena habitat suitability analysis in GNPS. The overall classification accuracy was done to know the validity of the model. We also used receiver operating characteristic (ROC) for assessing the accuracy of the model.

Results

Population estimation

A total of 150 trap-nights of sampling effort was expended at each zones and with total of 600 trap-nights from all four zones over six months from December 2007 to May 2008, and as a result 34 usable striped hyena photographs were obtained with an average trapping effort of 17.6 trap-nights per hyena photograph.

The effectively sampled area of capture-recapture sampling was calculated for central as 132.37 km^2, for east 145.44 km^2, for NP 159.03 km^2, and for west 132.29 km^2. The estimated adult striped hyena density for central was 3.78 striped hyena/100 km^2, for east 11.69 /100 km^2, for NP 7.55/100 km^2, and for west was 2.27/100 km^2. The mean density of striped hyena for the GNPS was calculated as 6.50 striped hyena/100 km^2.

Food and feeding habits

Analysis of 699 striped hyena scats from GNPS showed that 12.92% scats were found to have single mammalian prey item, while only 0.43% scats were found with five prey items. The minimum number of mammalian hair to be examined per scat to detect all mammalian prey species in a particular striped hyena scat in GNPS with 95% certainty was found at 21 hairs. The 'Observation area-curve' shows that the all striped hyena prey species could be detected by analyzing 40 scats.

A variety of food items were identified in the diet of striped hyena in GNPS, including large mammals to small rodents, birds, insects and even fruits. Total 12

mammalian prey species were detected. Chital was found to be the most common prey item in the diet of striped hyena. Seasonal variation in the diet was observed in the mammalian as well as non mammalian prey items. Significant differences were observed in diet composition in different zones of GNPS. On average 50.91% of total relative consumed biomass was contributed by the wild prey while livestock contribution was found as 49.08%.

Habitat use

Striped hyena was found around all the habitat type with preference of Mixed forest (40.46 ± 5.97 SE) and others as Moist mixed forest (8.09 ± 1.13 SE), Teak-*Acacia-Zizyphus* (30.64 ± 4.5 SE), *Acacia-Tectona/Anogeissus* (1.16 ± 0.06 SE), *Acacia-Lannea-Boswellia* (8.67 ± 1.22 SE), *Acacia-Zizyphus* ((8.67 ± 1.22 SE), Scrubland (1.73 ± 0.17 SE), and Open area (0.58 ± 00 SE) and no difference was observed in the seasonal habitat use pattern. Significant difference between two habitats that is Mixed forest and *Acacia-Lannea-Boswellia* in lion, leopard and striped hyena habitat utilization was observed in GNPS.

Mixed forest is most preferred habitat type by striped hyena in GNPS. Habitat types like Moist mixed forest, *Tectona-Acacia-Zizyphus*, *Acacia-Lannea-Boswellia*, Thorn forst, Scrub lands and open area were utilized in proportion to its availability, while *Acacia-Tectona/Anogeissus*, savanna and wetlands were avoided. Tree density was found as negative and grass was found as positive correlated with the striped hyena density in GNPS.

Denning and behavior

A total 28 dens and 30 resting sites at six locations were searched from different parts of GNPS. All were found in hilly terrain and most of them in middle of the hill slope and some of them on top of the hill. Out of 28 dens 23 dens were sandy and only 5 were rocky, while out of 30 resting sites 24 were sandy and only 6 dens were rocky.

The striped hyena uses three types of structures for the resting and pup rearing, resting sites, resting den and rendezvous site in GNPS. The mean litter size was found 3 ± 0.24 SE, ranges from 2-4 pups. The newly born pups were observed in winter from January – March (n=9) and age was estimated from body size. Striped hyena was found solitary at all the active times but clans (a group of hyena) was observed at den site. Mean number of individuals in clan was estimates with confidence interval as 3.74 ± 0.05. The largest clan was of 8 individual and smallest of 3 individuals in GNPS. Mother usually stayed with pups in the same den, seldom moves out of den but remains in close proximity when pups are very young (1-3 month), and mothers were observed resting at far place around 50m to 150m (n=5), in day time when pups became little old. The mean duration of lactation with 95% confidence interval was 12.94 ± 1.09 minutes that vary from 5-25. The striped hyena was found very calm animal that rarely uttered any sound.

Habitat suitability modelling using remote sensing and GIS

The geo-coded FCC of Landsat-TM was digitally analyzed. The forest cover and land use map (habitat map) of the study area was prepared through digital analysis of satellite data using supervised maximum likelihood classification technique. Normalized difference vegetation index (NDVI) was used for preparation of forest density map. The NDVI values were grouped into four canopy density classes *viz.*, <10% (non-forest), 10–40% (open), 40–70% (medium) and >70% (dense). Image elements like tone, texture, shape, size, shadow, location and association were evaluated for this purpose. The coefficients derived from BMLR were used to integrate all layers to arrive at the probability/suitability maps. Suitability map was further categorized into four classes i.e., highly suitable, suitable, moderately suitable and least suitable.

For modelling environmental factors were used as independent variables and striped hyena evidence (direct/indirect) were considered as Boolean (dependent

and intersected). Results indicated that 1108.65 km² (78.51%) of GNPS area is highly suitable to suitable for striped hyena. The overall classification accuracy of 86.5 percent was observed which depict, that model is only 13.5 present away from the ideal. The model performance assessed by the area under the ROC curve was found 0.902 implying that the present model is an effective model. Habitat suitability modelling accurately predicted striped hyena habitat with respect to density in GNPS. The model output can easily be interpreted by experts and managers, having thereby a great practical importance and would serve as baseline for future management planning for the conservation of the species. We concluded that GNPS is appropriate to serve as important conservation area for striped hyena in India.

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CERTIFICATE

This is to certify that the thesis titled "**Status, Ecology and Conservation of Striped Hyena *Hyaena hyaena* in Gir National Park and Sanctuary, Gujarat**" submitted for the award of Ph.D. degree in Wildlife Science, of the Aligarh Muslim University, Aligarh is original research work of **Mr. Md. Shamshad Alam.** This work has been done by the candidate under my supervision.

Jamal A. Khan

DEDICATED TO MY PARENTS

Photographs: Md. Shamshad Alam

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CONTENTS

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Md. Shamshad Alam

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CHAPTER- 1

INTRODUCTION

1.1 General account

Hyenas are scavenger by habit (Prater, 1971; Kruuk, 1975; Kruuk, 1676; Boitani and Bartoli, 1986; Hofer, 1998; Macdonald, 1984). They seek their food by scent. All in all, the animal is built neither for attack nor for swift pursuit of prey. Its structure fits its particular mode of life, which is to feed on prey killed by other animals (Prater, 1971).

General appearance of hyena suggests its relation with the Dog family, but the structure of skull, the teeth and other points of anatomy placed it in the felids or Cat family of the order Carnivora. Due to these considerations hyenas are placed in separate family Hyaenaidae (Prater, 1971). Family Hyaenidae having four species in three genera, Spotted hyena (*Crocuta crocuta*), Brown hyena (*Hyaena brunnea*), Striped hyena (*Hyaena hyaena*) and Aardwolf (*Proteles cristatus*).

According to Macdonald (1984), hyenas have thickset muzzles with large ears and eyes, powerful jaws and big cheek teeth to deal with a carnivorous diet. They walk on four-toed feet with five asymmetrical pads and non-retractile claws. The tail is long and bushy. Hyenas have no scent gland, but having anal gland also known as anal pouch hung above the anus. Anal pouch is one of the distinctive features of all hyaenids, which is used for the scent marking. As animal moves

forward over a grass stalk, they extrude a pest like secretion on it. Scent marks are placed throughout the territory (averaging 2-3 marks per kilometer), but the rate of pasting nearly doubles in the vicinity of border.

The hyenas are distributed in Africa except Sahara and Congo basin, Turkey, and Middle East to Arabia, SW USSR and India (Prater, 1971; Kruuk, 1976; Macdonald, 1984). They prefer chiefly dry, open grassland and brush and like open plains, deserts, rocky scrub covered hills and nullahs, grass or open forest. They usually avoid the interior of heavy forests and live more commonly in the drier area (Prater, 1971).

Height and weight of hyenas vary from 40cm-90cm and 8 kg-80 kg respectively. Spotted hyena is largest and aardwolf is smallest member of the family (Prater, 1971; Macdonald, 1984).

Hyenas are scavenger and feed chiefly on carcasses of animals. The hyenas feed mostly on bones and coarse remains. The powerful jaws of hyena and its large teeth are admirably adapted to bone crushing mechanism (Prater, 1971; Kruuk, 1976; Macdonald, 1984). As a scavenger the hyena is a useful animal, helping to keep the neighborhood of human settlement clean. Hyena performs an efficient function of sanitizing the ecosystem and recycling the precious nutrients like calcium and phosphorus locked up in the carcasses of dead animals by chewing up even large bones (Prater, 1971; Jhala, 2002).

1.2 The striped hyena

1.2.1 Prior study

Although striped hyenas are big carnivore, but we still know very few about the animal ecology, social organization, and behavior etc. Very little studies have been done, and only few study publications from Africa (Kruuk, 1976; Leakey, et al., 1999), Israel (Macdonald, 1978; Bouskila, 1984; Ilani, 1975; Kerbis-Peterhans and Horwitz, 1992; Skinner and Ilani, 1979), India (Davidar, 1990), and in captivity by Rieger, 1978, 1979a and 1979b. However, most of data are based on anecdotal information and were brief and relatively informal. Only systematic study was conducted by Wagner (2006), on behavioral ecology of striped hyena in Laikipia District, Kenya. In this research relatedness and relationships was estimated using microsatellite loci with null alleles and also other behavioral aspects were studied.

1.2.2 Distribution

Of the four extent species of hyena only Striped Hyena (*Hyaena hyaena*) occurs in India. The striped hyena is distributed over North Africa, Turkey, Arabia, Jordan, Iraq, Iran, Afghanistan, Pakistan and much part of India (Prater, 1971; Kruuk, 1975; Kruuk, 1976; Boitani and Bartoli, 1986; Hofer and Mills, 1998; Macdonald, 1984, Mayas et al., 2004, Max et al., 2004). The current distribution pattern of striped hyena was reviewed by Hofer and Mills (1998) (Fig. 1.1), and according to them the distribution of striped hyena is now patchy in most places, suggesting that it occurs in many small isolated populations and having very large

range extending from East and North East Africa, through the Middle East, Caucasus region, Central Asia, and into the Indian subcontinent. According to Hofer (1998), five subspecies of striped hyena are distinguished, mainly by their differences in size and pelage, although this classification is provisional.

1. *Hyaena hyaena barbara* from north west Africa,
2. *Hyaena hyaena dubbah* from north east Africa,
3. *Hyaena hyaena sultana* from Arabia,
4. *Hyaena hyaena syriaca* from Asia Minor and the Caucasus, and
5. *Hyaena hyaena hyaena* from India.

The striped hyena historically widespread throughout most part of India except for regions of deciduous evergreen forest in the southwest. In southern India the distribution is peculiar. It is present in the dry prone area (<900mm rainfall) of the Deccan plateau but is not found in heavier dense forest (>1000mm rainfall), nor in evergreen and semi-evergreen forms of Western Ghats (1500-6000mm rainfall) (Hofer and Mills, 1998). It is present in the northern strip of the coastal plains in Karnataka and Goa state, up to western Ghats (4000 to 6000mm rainfall) where the original evergreen forms are now entirely replaced by cultivation. Once they were common all over the Karnataka, apparently becoming scarce everywhere (Karanth, 1982, 1986). In northern and eastern India it also continues to exist outside conservation areas and also near the human settlements. In many conservation area throughout the subcontinent including Ranthambore, Kanha,

Palamau, Madhumalai, Bandipur, Anamallai, Jawahar and Corbett (Nair et al., 1977; Kothari et al., 1989), Gir National Park and Sanctuary (Singh et al., 1996; Saharia, 1998; Sinha, 2004; Upadhyay, 2004), Sariska (Saharia, 1998) and Kutch (Jhala, 2002), and reported at maximum altitude of 2,500m (Hofer, 1998).

1.2.3 Morphology

The striped hyena is one of the large carnivores, with adult weighing between 30 to 40 kg. The length of the head and body vary 90 to 120 cm and tail about 31cm. (Prater, 1971; Macdonald, 1984; Boitani and Bartoli, 1986; Hofer, 1998; Menon, 2003; Sinha, 2004). They are dog like animal and have a back sloping downwards towards the tail, with dark throat patch, thicken skin and denser fur (Harrison, 1968). The fore legs are taller and more powerful then hind legs. Legs appear thin relatively to their length and the hind legs are shorter than the forelegs. Feet have four toes with four short, non-retractable claws (Pocock, 1916).

The colour varies from cream, buff or tawny to the gray or dirty white with vertical black stripes, which gives the animal its name. The legs also have stripes on them. On the back there is a conspicuous, darker erectile crest. Pelage coloration varies by region and may vary seasonally in colder parts of its range (Pococke, 1934; Rosevear, 1974; Ilani, 1975). Differences in pelage across the species range appear minimal, although the Lebanese population is reported to have a reddish base coat colour (Lewis et al., 1968) and hyenas on the Arabian Peninsula are described as having a yellow mark below the eyes (Gasperetti et al.,

1985). Longest hairs are up to 200 mm long (Rosevear, 1974) and fall along the mid-dorsal line. The brownish black dorsal mane may be held erect, significantly increasing the apparent size of the animal (Pocock, 1934; Kruuk, 1976; Rieger, 1978). Striped hyenas tail is long with long coarse hairs and have well developed anal pouch, a slit-like glandular orifice over-arching the anus from either side. The anal pouch may be inverted and thus apparent while pasting during social encounters (Fox, 1971; Kruuk, 1976; Rieger, 1978).

The skull being slightly smaller and less massive in build than the spotted hyenas (Rosevear, 1974). Permanent dentition is distinctly carnassials and the dental formula is i 3/3, c 1/1, p 4/3, m 1/1 = 34. Compared with spotted hyena, the upper molar is much larger, as much as twice or more the size of the first premolar (Rosevear, 1974; Coetzee 1977).

1.2.4 Habitat

The striped hyena generally favors open or thorn bush areas in arid to semi-arid environments (Prater, 1971; Rosevear, 1974; Kruuk, 1976; Rieger, 1978; Leakey et al., 1999; Wagner, 2006), and avoid open desert and dense thickets and forests (Rosevear, 1974; Rieger, 1979a; Heptner and Sludskii, 1980), where water is available within 10 km (Rieger, 1979a), and favour large caves for resting (Kruuk, 1976; Rieger, 1979a; Leakey et al., 1999). Rocky ridge are used for dening if area is hilly and undulating (Kruuk, 1976). From India no publish information is available on habitat of striped hyena.

1.2.5 Population status

The striped hyena occurs at low population densities throughout its distribution range. The only quantitative estimate of striped hyena density in Africa comes from the Serengeti National Park, based on observation of limited number of individuals, where density was estimated as greater than 0.02 striped hyena per km^2 (Kruuk, 1976), and from a large study in Laikipia District, Central Kenya, estimated the minimum regional density at 0.03 adult striped hyena per km^2 (Wagner, 2006). For comparison, spotted hyena in the same ecosystem have been estimated to exceed 1 individual per km^2, and 0.02 per km^2 and 0.03 per km^2 is substantially lower than the densities of spotted hyenas, lions in most ecosystems, and even lower than the density of endangered African wild dogs (Creel and Creel, 1996).

In India striped hyena is a data deficient species. According to Hofer and Mills 1998, total Indian population estimate 1,000 to 3,000 individuals representing around 18% to 20 % of the total world population estimate of 5,285 to 14,670 individuals. The total African population estimates 2,450 to 7,850 individuals represent roughly half of the world wide estimated population.

Population is declining in many places due to persecution and hunting for utilization. Ecological factors may also be contributing to the decline, including diminishing food stocks and competition with leopards over shelter (Heptner and

Sludskij, 1980). In India hunting is prohibited under the Wildlife (Protection) Act 1972, schedule III.

1.2.6 Adaptations

Ducts from the anal glands open into an anal pouch dorsal to the anus. The pouch is inverted during pasting and greeting behaviour (Fox, 1971; Kruuk, 1976; Rieger, 1978, 1981). It is not known if pasting is used to mark territories.

The high sagittal crest of the skull increases the area of origin for the temporal muscles and the well developed masticator muscles facilitate seizing and crushing of prey (Buckland-Wright, 1969). There is no sexual dimorphism in body measurements and weight in striped hyena (Kruuk, 1976).

1.2.7 Food habits

The structure of hyenas fits for its particular mode of life, which is feed on prey killed by other animals (Prater, 1971). The striped hyena is classic scavenger, existing around human settlements and feeds on dried bones, carcasses and also on fruits, insects and reptiles (Kruuk, 1975; Kruuk, 1976; Hofer, 1998). Striped hyenas have been reported to consume a wide variety of vertebrates, invertebrates, vegetables, fruit, and human originated organic wastes (Harrison, 1968; Ilani, 1975; Kruuk, 1976; Macdonald, 1978; Leakey et al., 1999; Wagner, 2006) and this limited data has led to the interpretation that striped hyenas are essentially omnivorous scavenger.

In Israel, groups of hyenas converge at feeding sites (Kruuk, 1976; Macdonald, 1978; Bouskila, 1984), but relatedness of observed groups has not been investigated. Foraging activity in Tanzania was restricted entirely to night-time (Kruuk, 1976). Striped hyenas have also been described as raiding human grave sites and carrying away bones (Horwitz, 1988; Leakey et al., 1999), and fruit and vegetable crop raiding is considered a serious problem in Israel (Kruuk, 1976).

The striped hyena is also known for occasional killing of livestock (Prater, 1971; Kruuk, 1976; Hofer, 1998). There are records of attacks by striped hyena on sheep, goat and donkey from North Africa, Israel, Iran, Pakistan and India, on horse in Iran and on dogs in India (Hofer, 1998).

1.2.8 Behavior

The striped hyena has been considered exclusively nocturnal and solitary (Prater, 1971; Kruuk, 1976; Macdonald, 1984; Boitani and Bartoli, 1986; Menon, 2003). Also during the night they spend a considerable time in resting. The animal appeared to be more active in the first part of the night followed by a period of rest and becomes again active in last part of the night. The striped hyena spends greater part of the activity in searching for food. There range is relatively large in Serengeti for instance; one radio collard female had range of 44 km^2 and a male had a range of 72 km^2. (both were 1 ½ - 2 year old). Striped hyena covered a mean

distance of 19 km per night with a shortest distance per night of 7 km., the longest 27 km. data from ten 24- hr observations (Kruuk, 1976).

The meeting ceremony between greeting pairs involved mutual sniffing of the face, neck, and anal regions. During these encounters, the anal pouch was protruded during sniffing and either both hyenas were standing or one would lie down while exposing the anal region (Kruuk, 1976).

1.2.9 Reproduction

Gestation period is 90-91 days and there is no apparent seasonal pattern (Pocock, 1941; Ronnefeld, 1969; Heptner and Sludskii, 1980). Litter sizes in the captivity range from 1-5 pups (Rieger, 1981). Weaning in captivity takes place after eight weeks and sexual maturity reached at 2-3 years.

Striped hyena pups are reared in dens and intense digging behaviour in the females announces parturition (Rieger, 1979a). Dens may be holes dug by the mother, holes formed and abandoned by other species (Prater, 1971) or deep, natural, and sometimes complex, caves (Heptner and Sludskii, 1980; Kerbis-Peterhans et al. 1992; Leakey, et al., 1999). Mothers carry food back to the den for their pups (Kruuk, 1976; Davidar, 1985; Davidar, 1990) and prepare meat for pups by biting off pieces (Rieger, 1979a).

1.2.10 Predation and threats

The striped hyena considered subordinate to lions and spotted hyenas in African ecosystem, although Kruuk (1976) described a mutual attraction between the two Hyaenids. Humans are consistently indicated as the major source of mortality throughout the evaluated range (Hofer, 1998). Although, striped hyena is an important member of the ecosystem. But due to some cultural and economical value and due to habitat loss and fragmentation the population is declining (Hofer and Mills, 1998) and facing extinction in several ranges (Kruuk, 1976). The striped hyena is considered as data deficient and threatened animal in several areas of its geographical range (Hofer and Mills, 1998), and ecological information is needed for its conservation (Kruuk, 1976).

1.3 Other members of family Hyaenidae

1.3.1 Aardwolf

Aardwolf (*Proteles cristatus*), the a smallest member of family Hyaenidae. The size from head to tail tip 85-105 cm, height 40-50 cm and weight 8-12 kg. They are distributed from South Africa, North to South Angola and South Zambia; East Africa from Central Tanzania to North East Sudan. They prefer open country and grassland also savanna, scrubland and rocky areas. Aardwolf is a highly specialized forager on termites that lives in socially monogamous, territorial pairs with only their most recent dependent offspring (Richardson, 1987). Social pairs cooperate in raising young, but females commonly mate outside the pair-bond with neighboring males. Foraging in aardwolves is concentrated in time, as they

eat a large number of termites in a very short interval (Gittleman and Harvey, 1982). The aardwolf's diet is thought to constrain the evolution of social groups (Mills, 1989).

1.3.2 Brown hyena

Brown hyenas (*Hyaena brunnea*) is the second larger hyanides. The size from head to tail 110-130 cm, height 65-85 cm and weight 35-50 kg. They prefer drier areas often rocky with desert or thick brush. They live in small, female-bonded social groups that share and defend a common territory and den (Owens and Owens, 1979a, 1979b; Mills, 1978, 1989). Brown hyenas are well adapted to utilizing varied and sparse resources. They feed on carcasses and small prey which tend to be rare, widely dispersed, and provide food for only one individual (Mills, 1989). Because of their diet, foraging is primarily solitary, they do not cooperate in killing large prey, and there is no apparent benefit to foraging in groups. In brown hyenas, 33% of adult males become permanently nomadic and these males father the majority of pups (Mills, 1982). Resident, non-breeders of both sexes care for young at communal den sites, adult provision pups other than their own offspring, and mothers occasionally suckle the pups of other females (Owens and Owens, 1979a, 1979b). The solitary foraging behavior in brown hyenas may have constrained the development of larger groups and the rank related bias in reproductive success typical of many social carnivores (Mills, 1983, 1989).

1.3.3 Spotted hyena

The spotted hyena (*Crocuta crocuta*) is a largest member family Hyaenidae. The size from head to tail 120-140 cm, height 70-90 cm and weight50-80 kg. Spotted hyena is a communal hunter and scavenger of large mammals that lives in matrilineal, territorial social groups of up to one hundred individuals (Kruuk, 1972), and is the only hyaena in which females are dominant over males. Spotted hyena females stay in their natal 'clan' for life and form the stable core of the social group. Immigrant males father the majority of offspring in spotted hyena clans, there is a dominance hierarchy among males, and reproductive success of males is positively correlated with social rank and clan tenure (Mills, 1989). Reproductive success is also linked to rank in females, but in a manner unusual for carnivores, because younger females are dominant to older members of the same lineage. Age does not predict dominance (all of the descendants of the alpha female are dominant to all of the females in other lineages). Spotted hyenas do not suckle pups of other females and do not provision the pups of others at dens (Mills, 1989). Spotted hyena lactate for more than a year, in comparison to lactation periods of a few weeks to a few months in most carnivores. Prolonged maternal suckling of offspring has been interpreted as either a constraint on, or effect of, intense competition for feeding access at carcasses. Spotted hyenas specialize in feeding on relatively large prey items that provide enough food for more than one individual and the benefits of cooperative foraging (being greater than the costs of feeding competition) are considered to be the initial selective pressures favoring group formation in the species (Kruuk, 1972; Mills, 1989).

1.4 Need of this study

Gir National Park and Sanctuary (GNPS) is a heritage (Pati, 2000), supports rich biodiversity of 39 species of mammals, 32 species of reptiles, more than 300 species of birds, 450 species of flowering plants and more than 2,000 species of insects (Singh and Kamboj, 1996). GNPS has given a significant result in term of Asiatic lion conservation and also given an umbrella protection to many other endangered and rare species. The GNPS supports a high density of carnivore population, namely, Asiatic Lion (*Panthera leo persica*) and Leopard (*Panthera pardus*). In GNPS, these predators are known to feed on each other kills. The competition for scavenging by the predators with that of the natural scavengers like hyena could have significant impact on the population dynamics. In this context the role of striped hyena in the Gir ecosystem seems to be crucial which needs to be understood. Status, distribution and ecology of striped hyenas was unknown till this study happen in this great protected area, and there was urgent needs to be understood at basic levels for the better management and conservation.

1.5 Objectives of this study

1. To investigate the current status, distribution and abundance of striped hyena in different management units and habitats of Gir National Park and Sanctuary.
2. To investigate feeding ecology of striped hyena in Gir National Park and Sanctuary.
3. To investigate the habitat use of striped hyena in Gir National Park and Sanctuary.
4. To investigate the social organization and behavior of striped hyena in Gir National Park and Sanctuary.
5. To evaluate the habitat suitability model for striped hyena in Gir National Park and Sanctuary.

Fig. 1.1: Global distribution of the striped hyena (*Hyaena hyaena*).
Source: IUCN (International Union for Conservation of Nature), The IUCN Red List of Threatened Species. Map created on 10th January 2008.

CHAPTER-2

STUDY AREA

2.1 Introduction

The Gir forest was part of the former state of Junagadh and Baroda. Forest were mainly managed and worked with an idea to get revenue and for shooting the wild animals by ex. rules. In addition to the sale of timbers and other forest produce, grazing fees were also charged.

Gir National Park and Sanctuary (GNPS) is the only home of Asiatic Lion (*Panthera leo persica*) in the world and a resort of many threatened species. It supports a rich biodiversity comprising of about 450 recorded flowering plant species, 39 species of mammals, 26 species of reptiles, about 300 species of birds and more than 2000 species of insects.

2.2 Location and size

GNPS lies 40 km from the coast in the Kathiawar peninsula also known as Saurasthtra peninsula of Gujarat situated between 20° 40' to 21° 50' N latitude and 70° 50' to 71° 15' E longitude. It stretches over a length of about 70 km from west to east and 40 km from north to south. The sanctuary is narrowest at the east and west ends. In 1877, Gir forest covered 3,107 km^2. Uncontrolled commercial exploitation of forest and expansion of human settlements over the years reduced it to present size. The total area of GNPS extends to 1412.13 km^2 of which the

national park comprises of 258.71 km² surrounded by 1153.41 km² of sanctuary. Another area known as Pania sanctuary of 39.63 km² in Dalkhania range constitutes an integral part of Gir forest also been included as part of the Gir Conservation Unit (GCU). Additionally, there is a buffer area of Reserved forest (245.90 km2), Protected forest (107.51 km2) and Unclassed forest (77.19 km2) comprising of valuable grassland and forests, makes the total wildlife protected area to 1869.37 km².

GNPS is divided into 16 ranges and 38 blocks managed by three deputy conservator of forests (DCF), namely two territorial divisions DCF (West Gir) with head quarter at Junagadh, DCF (East Gir) with head quarter at Dhari and the DCF (wildlife) with head quarter at Sasan, reporting under the chief conservator of forest (CCF), Wildlife Circle Junagadh.

2.3 Topography

Gir forest is hilly and undulating hills extend one after another in different directions. The altitude range from 152 m in western part of Gir to 648 m at Sarkala hill in Pania Sanctuary. The Gir hills drop off to flat and valley areas. Small streams cris-cross the entire Gir that in turn join major rivers. Gir forms major catchments for 9 rivers of which 4 rivers have been dammed. The rivers are Hiran, shingavade, Machundri, Raval, Malan, Dhatardi, Shetrungi and Popatedi.

2.4 Geology and soil

Gir hills are of volcanic origin. The general formation of Gir hills consist of traps (basalt) of varying composition associated with granite and gneiss overlain by beds of calcareous sandstone which in part assume the nature of lime stone. The soil varies place to place. They are mainly laterite with patches of Black cotton soil in low lying areas. The other types of soil found are red, yellowish red, white clay and sandy loame. Water holding capacity is lowest on sandy loam and highest in black clay, which remains water logged during monsoon. Soil layer thickness varies in different areas which are up to 1 meter thick in valley areas.

2.5 Climate

The climatic condition of Gir is generally hot with an erratic monsoon. Season in Gir is fairly distinct. June through September is monsoon, followed by a post monsoon season. Late November to early March is winter season. Winter season is followed by a hot dry season from mid March to mid June.

The maximum and minimum temperature 44.4°C and 10°C respectively. Rainfall is erratic and irregularly distributed, maximum and minimum annual rainfall being 1866mm and 199mm respectively with an average being 980mm. Wind blows mainly from north-west to south-east during October to March and change south-east to north-west during summer and monsoon. Eastern portion of Gir is more arid than western Gir.

2.6 Drainage system

GNPS is drained by seven rivers namely Hiran, Datardi, Singhoda, Machundhry, Ghodavadi, Raval and Shetrunji. Four major reservoirs are there in Gir – Kamleswar, Shingoda, Machundri and Raval. All rivers, except Shetrunji, flow southwards and drain into the reservoirs. Numerous small seasonal streams flow through the forest. During the dry season, water is a limited resource and restricted to perennial rivers, reservoirs and deep rock pools of small streams. Drainage pattern of western Gir is subdendric to paralle or trellis. This is due to dykes and the large number of fractures that cuts across area in a definite pattern. In the eastern Gir the drainage pattern is mainly sub parallel to trellis. At higher altitudes it is radiating and dendritic. A prominent stream in the central part of western Gir forms a gorge. A majore part of the area that lies to the south of these water divides is drained by various rivers like, Jatardi, Ardak, Shinghoda and tributaries of Hiran in the west; and tributaries of Jamri and Ravel in the east.

2.7 Flora

According to Champion and Seth's revised classification of forest type, 1966, the area fall under the type 5A/Cia, i.e., very dry teak forests. Teak occurs mixed with dry deciduous species. The main forest types are as under.

TEAK FOREST (Type 5A/Cia): This type occupies nearly half of the area. The crown density varies from 0.3 to 0.6. The main associates of teak are khair, sadad, timbru, babul, amla, moledi, dhavado, kadayo and bahedo.

NON TEAK FOREST (Type 5DSI and 5DS2): The remaining half of the forest is occupied by this type of forest. Teak form less than 10 percent of total growing stock in these areas. Consist of khair, dhavdo, saded, timbru, babul, amla, moledi, teak, kadayo, saleri, bahedo, bor, khakhro, asundro etc.

RIVERINE FOREST: A distinct type of vegetation is found along the peripheral rivers and streams. The main species are jambu, karanj, umro, vad, kalam, charel, siru and amli etc.

COSTAL BORDER FORESTS: These are areas afforested in the recent past along the coastal borders. Saru and Gandobaval are the two main species raised in the areas. The oldest plantation is of 1965-1966, and few of them have attained maturity.

Composition of important tree species in GNPS in descending order is -*T. grandis* (31.3 %), *Wrightia tinctoria* (11.2 %), *A. catechu* (9.2 %), *Zizyphus mauritiana* (7.5%), *A. nilotica* (4.2%), *Anogeissus latifolia* (3.9%), *A. leucophloea* (3.4%), *Terminalia crenulata* (3.1%), *Diospyros melanoxylon* (2.4%), *Bauhinia purpurea* (2.4%), *Grewia tiliaefolia* (1.9%), *A. ferruginea* (1.8%), *Boswellia serrata* (1.7%), *Lannea corromandelica* (1.5%), *Butea monosperema* (1.3%), (Sharma and Johnsingh, 1996).

2.8 Fauna

GNPS has a divers fauna having 39 species of mammals, about 300 species of birds (Appendix-II), 37 species of reptiles, and more than 2000 species of insects. The main carnivores found in the forest are lion, leopard, striped hyena, fox, jackal, cats, mongoose and ratel. Main herbivores are chital, sambar, nilgai, four horned antelope, chinkara, wildboar etc. Monkey, porcupines and hares are also found. Crocodiles are found in water reservoirs. Pangolin and python are found with occasionally. The main birds found in the tract are peafowl, quils, partrige, nightjar, heron, black ibis, vultures etc., the predator birds being owl, shikra, brahmini kite etc.

2.9 People

The economy of Gir is farm based agriculture, horticulture and animal husbandry. In recent years, in the western and southern boundary of Gir, the crop pattern has shifted from agriculture to horticulture with the introduction of kesar mangos as an important cash crop. With the replacement of intensive irrigation drought resistant traditional crops such as maize and bajra have been replaced by groundnut and sugarcane. There are 97 peripheral villages with over a lakh human population and over 90,000 livestock.

Small temporary settlements known as Nesses are occupied by *Maldharis* throughout GNPS. Though there is no authentic record of precisely when *Maldharis* arrived in Gir, they are there probably for the last 150 years. The

Maldharis are resident cattle graziers belonging to ancient tribes such as the *Charan, Bharwad, Rabari, Ahir* and *Kathi*; over 2000 *Maldharis* with 10,000 livestock in 54 nesses across the GNPS and about 4000 people in 14 forest settlements with a livestock of nearly 5000 are resident in the sanctuary.

2.10 Approach and access

GNPS is approachable by road from Junagadh-Mendarda-Talala and Junagadh-Visavadar state highways from Junagadh; Veraval-Talala-Sasan state highway from Veraval; Amreli-Dhari-Kodinar state highway from Amreli, Una-Tulsishyam-Dhari and Una-Jamwala state highways from Una. Sasan Gir is the main rail head situated on the meter gauge line of the Western Railway. It is 60 km from Junagadh and 40 km from Veraval via Talala. Veraval is well connected to Ahmedabad on broad gauge line via Junagadh and Rajkot. The nearest airport is Diu, 100 km from Sasan Gir. There is Air service from Mumbai to Diu.

2.11 The statement of significance

GNPS, the last abode of Asiatic Lions, falls in Bio-geographic Zone-4 (Semi arid) and Bio-geographic province 4-B Gujarat Rajwara. GNPS is the largest compact tract of dry deciduous forest in the Saurashtra region of Gujarat State and is synonymous with the majestic 'Asiatic Lion', *Panthera leo persica,* only gene pool in the world. The Gir ecosystem can take legitimate pride in saving the rare and threatened lion from the threshold of extinction at the beginning of this century by affording it a relatively secured habitat. The most important aspect is

that it has become a very stable eco-system with tremendous regenerating, self supporting and self sustaining capacity due to its rich and diverse flora and fauna.

The GNPS has earned global acclaim for its singular success under Gir Lion Sanctuary Project launched in 1972 which led to the comprehensive recovery of habitat and conservation of entire floral and faunal community. Gir Sanctuary was awarded the Challenge Trophy of the Chairman of the Indian Board of Wildlife for being the best managed Sanctuary in the country for the year 1975-76. GNPS is also proposed for inclusion in the list of 'World Heritage' by the Forest Department.

Gir is one of the oldest sanctuaries in the country harboring the Asiatic Lions which once was the National Animal of India. The area supports a rich biodiversity comprising of 448 different plant species. The Sag or Taek is commonest and forms over 31 percent of tree cover. It is a breeding ground for many migratory birds. the avifauna of Gir includes a variety of raptors and many other threatened species including lesser floricans, ospray, pitta, king vulture, griffin vulture etc. It also supports a variety of reptiles including the endangered Indian Python and Star tortoise. The area can also boast of harbouring possibly one of the largest population of Marsh crocodile *(Crocodiles palustris)* and also largest breeding colony of them in the country. Gir has one of the largest concentrations of leopards *(Panthera pardus)* in the country. Gir ecosystem thus

constitutes an important protected area of significant conservation value in Gujarat Rajwara biotic province of semi arid biogeographic zone of the country.

Conservation efforts for Asiatic Lions have been initiated from the beginning of the 20th Century. The results of the policy decisions and efforts for the Lion conservation are monitored by periodical estimation of the Asiatic Lion population. Available records indicate that such estimations were done by different methods. The pre-Indian independence period, however, was marked with estimates for which reliable detailed records are not available. Available records indicate that such estimations were done by different methods and for different area coverage. However, detail and well documented lions population estimates are available from 1963 onwards conducted by Gujarat Forest Department.

This ecosystem forms a part of south central highlands in Saurashtra region and is a catchment of important rivers like Shetrunji, Hiran, Saraswati, Shingoda, Machhundri, Raval and Datardi. The forest of Gir help recharge the water table due to infiltration and percolation in conjunction with soil and moisture conservation. The continuous forest covers over a large tract also exert significant moderating effect on the climate in the region. The Gir forest also helps in reducing the salinity problem on the southern coast of Saurashtra. Thus, Gir is a boon to farmers inhabiting the peripheral environs by ensuring sustained agricultural and horticultural production to them. Also, it is a potential place to be

a center for creating environmental awareness and imparting nature education. Presence of the Asiatic lion, aesthetic beauty of the area and famous Somnath temple near Gir have made this place a popular destination for visitors.

It has been observed that the increase in lion population due to adequate protection and better enforcement of conservation strategies have resulted in dispersal of lions outside GNPS. Lions are recapturing their lost territories in Girnar, Mitiala, Shetrungi river basin to forests of Bavnagar districts and also moved into coastal forests. A careful analysis of number of all these migrating lions indicate that increase in number of male lions might be one of the reasons of migration of lions from sanctuary in search of new territories. In recently conducted "13th Asiatic Lion Population Estimate" in April 2010 the concept of "*Brahad Gir*" (Greater Gir) emerged on the basis of last 10 to 20 years records of lions sighting, kill and indirect evidence data. And for the first time lion population estimation was conducted in areas of four districts namely Junagadh, Amreli, Porbandar and Bhavnagar.

The corridors which previously existed have been lost to cultivation and other commercial activity, and by lime stone mining at some extinct. This has detached Gir from Girnar, Babra vidi, Kanada hill, Malanka, Barda, Alech hill, Mityala, coastal forest and Shetrungi river basin. Gir has been converted into a terrestrial island engulfed by human settlements and cultivation from all around. However, lions still continue to stray into these areas. Further, it has been observed that dispersal route of the Asiatic lion is almost similar to the extinction path adopted

during the beginning of present century. By creating suitable corridors and improved prey base in lion territory can be expanded beyond sanctuary limit of Gir. The areas frequently visited by lions can safely be assumed as the ecological zone and that could be serves as safe refuge. Key indicator species, ecosystem linkages, similarities in ecosystems, corridors and historical background could be the main basis for deciding ecological boundaries of Gir. Hence, ecological boundaries of Gir now extend in forests of four districts namely Junagadh, Amreli, Porbandar and Bahvnagar.

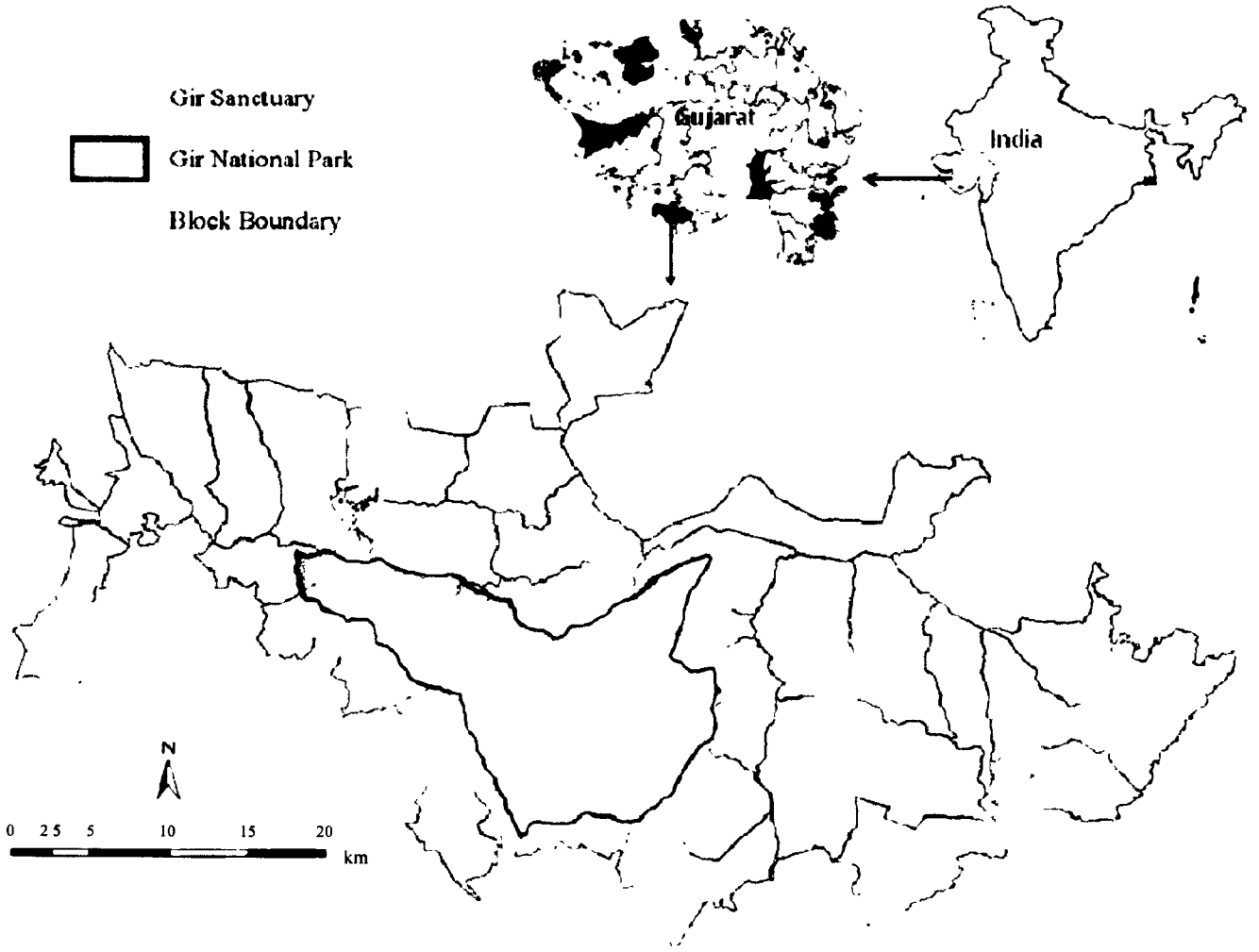

Fig. 2.1: Map showing study area Gir National Park and Sanctuary with their blocks, and location in Gujarat, India.

CHAPTER-3

STATUS AND DISTRIBUTION

3.1 Abstract

We report the first estimate of striped hyena density in the semi-arid tropical forest of Gir National Park and Sanctuary of western India. We used photographic capture-recapture sampling technique for estimating population of striped hyenas. Four zones were selected as; central, east, NP, and west in Gir National Park and Sanctuary to sample all the possible habitat types and management units. Total sampling effort expended on each site was 150 trap nights with total 600 trap nights from all the four sites, from December 2007 to May 2008. Total 34 usable striped hyena photographs were obtained with average trapping effort of 17.6 trap nights per striped hyena photograph, out of that total 24 individual hyena were identified. The estimated density for Gir central was 3.78 ± 0.99 $S\hat{E}$ individuals per 100 km², for Gir east 11.69 ± 3.53 $S\hat{E}$ individuals per 100 km², for Gir NP 7.55 ± 5.54 $S\hat{E}$ individuals per 100 km², and for Gir west 2.27 ± 1.86 $S\hat{E}$ individuals per 100 km². The mean density of striped hyena for the Gir National Park and Sanctuary was calculated as 6.50 striped hyena/100 km². This method is currently the only systematic population technique for striped hyena in Gir National Park and Sanctuary, and has the potential to be applied to other species with individually recognizable markings. This estimate is higher than in most other distribution ranges and indicates Gir National Park and Sanctuary as an important area for protecting striped hyena in India.

3.2 Introduction

Hyenas are scavenger by habit (Prater, 1971; Kruuk, 1976; Boitani and Bartoli, 1986; Hofer, 1998; Macdonald, 1984). They seek their food by scent. All in all, the animal is built neither for attack nor for swift pursuit of prey. Its structure fits its particular mode of life, which is to feed on prey killed by other animals (Prater, 1971).

General appearance of hyena suggests its relation with the Dog family, but the structure of skull, the teeth and other points of anatomy placed it in the felids or Cat family of the order Carnivora. Due to these considerations hyenas are placed in separate family Hyaenaidae (Prater, 1971). Family Hyaenidae having four species in three genera; Spotted hyena (*Crocuta crocuta*), Brown hyena (*Hyaena brunnea*), Striped hyena (*Hyaena hyaena*) and Aardwolf (*Proteles cristatus*).

In India only striped hyena is found. Although, this is a big carnivore species, but we still know very few about its ecology, social organization and behaviour in India as well as its other geographical ranges of the world. Very little studies have been done, and only few study publications from Africa (Kruuk, 1976; Leakey et al., 1999), Israel (Macdonald, 1978; Bouskila, 1984; Kerbis-Peterhans and Horwitz, 1992; Skinner and Ilani, 1979), India (Davidar, 1990), and in captivity by Rieger, 1978. However, most of data are based on anecdotal information and were brief and relatively informal. Only systematic study was conducted on behavioural ecology of striped hyena in Laikipia District, Kenya (Wagner, 2006).

The striped hyena occurs at low population densities throughout its distribution range. The only quantitative estimate of striped hyena density in Africa comes from the Serengeti National Park, based on observation of limited number of individuals, where density was estimated as greater than 0.02 striped hyena per km^2 (Kruuk, 1976), and from a only large study in Laikipia District, Central Kenya, estimated the minimum regional density at 0.03 adult striped hyena per km^2 (Wagner, 2006).

The assessment of the current status and population trends of the striped hyena is complicated by a number of problems, like its nocturnal habit, solitary behaviour and occurrence in low densities. Sightings are infrequent and surveys difficult to carry out. The result of survey and evaluation of published information suggest that the striped hyena is already extinct in many localities and the population are generally declining throughout its geographical range due to persecution and hunting for utilization and is considered as Data Deficient and ecological information is needed for its conservation (Kruuk, 1976; Hofer and Mills, 1998). Ecological factors may also be contributing to the decline, including diminishing food stocks and competition with other carnivores over shelter. The striped hyena is categorized on the IUCN Red List as Near Threatened. In India hunting is prohibited under the Wildlife (Protection) Act 1972, schedule III. According to Hofer and Mills 1998, total Indian population estimate is around 1,000 to 3,000 individuals representing around 18% to 20 % of the total world population estimate of 5,285 to 14,670 individuals. The total African population estimates

2,450 to 7,850 individuals represent roughly half of the world wide estimated population.

Gir National Park and Sanctuary (GNPS) has given a significant result in term of Asiatic lion conservation and also given an umbrella protection to many other endangered and rare species. The GNPS supports a high density of carnivore population, namely, Asiatic lion (*Panthera leo persica*) and Common leopard (*Panthera pardus*). Although estimation of density is a basic requirement for assenting the status of a species. The population of striped hyenas was unknown in GNPS and there was urgent need for the better management and conservation. Towards this effort present study was conducted to assess current distribution and population density of the striped hyena in GNPS.

3.3 Methodology

It is important to assess the status and distribution of animals and to monitor population trends, especially in the case of rare or endangered species. However, as in the case of most carnivores (Roughton, 1982; Kumar and Rahmani 1997; Sutherland, 1997), this is also extremely difficult to do with striped hyenas as they are nocturnal and occur in very low densities (Kruuk, 1976; Wagner, 2006). Accordingly, some special techniques have been developed or established methods modified to accommodate particular situations. For striped hyena methods like questionnaire surveys, extrapolation, Lincoln index, identification of

individuals and tracks, signs and vocalizations (Mill, 1998) and capture-recapture method using photo camera trap (Karanth, 1995) may be used.

We used photographic capture-recapture sampling technique using remotely trigged camera traps to obtain the estimate of striped hyena density in one of the India's most important protected areas.

3.3.1 Camera trap survey

Individual striped hyenas can be identified easily as each has a unique striped pattern that differs individual to individual. Because direct sightings of hyenas are extremely rare in GNPS, due to its nocturnal and shy habits, the identification of individuals is only possible using camera trap photography. Photographic capture-recapture estimates of the abundance of a large cat was obtained for tigers in India (Karanth, 1995), and a great deal of work followed, further developing this technique for estimating densities of naturally marked species, which has led most researchers to conclude that this method holds the most promise for estimating absolute abundance of large elusive carnivores. Carnivores normally use game trails and roads for their movements, and placing camera traps in strategic positions along these travel routes will deliver photographic captures of individual using the study area.

There is often little choice in defining a study area, as it may be dictated by jurisdictional boundaries, habitat divisions or by logistics (Henschel and Ray,

2003). The accuracy of the density estimate increases with population size, as the larger the area, the smaller the 'edge effect'. Like all large carnivores, striped hyenas maintain home ranges and that must be large enough to provide them with sufficient food year round. The minimum known home range of striped hyena is given by a radio collard female 44 km^2 (Kruuk, 1976), and by another radio collared female 36 km^2 (Wagner, 2006). The study area should ideally be large enough to contain at least parts of the home ranges of several individuals (Henschel and Ray, 2003). For most camera trap studies, the number of units available is usually the limiting factor. It is, however, crucial to the sample design that the whole study area is evenly covered with traps, and that none of the individuals present has a zero chance of being captured (Karanth and Nichols, 1998, 2002). If fewer camera units are available, the solution is to subdivide the area into smaller subsections and sample them one by one (Karanth and Nichols, 2002).

3.3.2 Camera traps and sampling design

Ten units of commercially made Camtrakker brand passive camera trap units (Manufactured by Camtrakker South, 1050 Industrial Drive, Watkinville, Georgia, supplied by Forestry Suppliers, Inc) were used (Fig. 3.1). Out of ten units, five were with digital camera (Sony Cyber shot 6 mega pixels) with extra flash strobe and five were with fully automatic Canon 35 mm cameras. Camtrakker units comes with a heat-in-motion detector, operates on a horizontal plane. When some thing that moves and gives off heat, a silent electronic switch engages the camera.

which takes a photograph. To obtain clear photographs, digital camera trap were set with the high resolution photograph and in canon 35mm cameras Kodak Max 400 36 exp. films were used to obtain bright and clear photographs in the night. A unique identification numbers were given to each Camera trap unit and each film roll before loading avoiding any mix-up. Digital units come with rechargeable batteries, and in other ones Duracell AA and Novino 'C' sized cells were used for the power. Cells and batteries were regularly checked using a multi-meter.

All the camera traps were mounted as described by Karanth et al. (2004). Camtrakker units are equipped with a delay selector mechanism that precludes the camera from taking a photograph for a set period of time. The time delay between photographs was set to a minimum of 20 seconds. All the camera traps were kept active in night mode. For complete identification of a striped hyena it was necessary to acquire photographs of both sides of its body. The stripe pattern is different on each side, so photograph of the left side of an individual striped hyena tell us nothing about the right side. Therefore two camera traps were set up on each side of the trail at each station. Camera units were mounted with tree in such away so that striped hyena both flanks would clearly photographed. Wherever suitable trees were not found locally made iron pole with camera trap adjustment screw were used. To avoid flaring of photo from mutual flash interference, two cameras were not positioned directly facing each other. All the camera trap stations were identified by giving a code on local name of the area as well as with

Global Positioning System (GPS) location, and care was taken to match the film roles, date, and camera trap unit with their respective camera trap station.

We overlaid a grid of 2.5 km × 2.5 km on the study area, and selected 15 grids in four zones; east, central, NP (National Park), and west systematically to cover all the habitat type and management units (Fig. 3.2). Grids of each zone was searched on foot and using a motorcycle and on the basis of evidences most appropriate site in each grid was selected as camera trap station in this way total 15 station were selected in each zone. Each zone further divided into three sub-zones of 5 grids. At a time one sub-zone was sampled where camera trap were mounted for continuous 10 days or 10 trapping occasions, in this way one zone was covered in 30 days with total effort of 150 trap nights. At least additional 10-15 days were given to each zone for evidence survey and camera trap station selection. Total trapping occasions were continuous except for climatic and logistical constrains. In west zone (part of this area is also open for ecotourism) of camera trap survey all the units were daily mounted and removed from station to avoiding depiction to the people and vandalism, and in other three zones units were kept mounted for continuous 10 days with night mode activation, and checked at-least each alternate day. All the camera trap stations were marked on a map using a GPS receiver.

3.3.3 Identification of individual striped hyena

The photographs obtained were of good quality, and useful. Striped hyena were identified and separated as individuals on the basis of their asymmetrical stripe pattern (Karanth, 1995; Karanth and Nichols, 1998; Azlan and Sharma, 2003). Both side photographs were used to identification of individual. It was not possible to classify the sex of striped hyena in the photographs due to equal appearance of male and female and invisible sex organs and denoted as HY with the zone mark E-east, C-central, N-NP, and W-west, like HYC1, HYC2, HYE1... and so on.

3.3.4 Assumptions and data analysis

Mark-recapture is based on a closed population assumption. The closed population assume that no birth, death, immigration or emigration within the study area during the sampling period (Pollock et al., 1990). Since no population is closed in the wild situation and to meet this assumption in field (Karanth and Nichols, 1998) limit the study for short duration and recommend that there should be reasonable time frame to assume a closed population. Every individual inhabiting the area of interest has at least some probability of being captured i.e. photographed by the camera unit. Thus there should be at least one camera unit within its ranging area of an individual during the study period.

The program CAPTURE (White et al., 1982; Rexstad and Burnham, 1991) was used to analyse the capture and recaptured photograph data of striped hyena. This

program uses a number of different models to generate abundance estimate for sampled area, based on number of individual animal captured and frequency of recaptures. These models differ in their assumed sources of variation in capture probability, including the simplest model, the null model (M_0), assumes no differences in capture probability in between different individuals and sampling occasions, variation among individuals in trap response (M_b), over time (M_t), heterogeneity that each animal has its own unique capture probability (M_h), and various combination of these (e.g. M_{tb}, M_{th}, M_{bh}, M_{tbh}). CAPTURE also has a model selection function that analysed the data set to determine which model and which estimator best fits for the data. CAPTURE software computes a closer test statistic to test the closed population assumption for each data set and gives number of individuals in the study area and associated standard error of abundance. Density estimate were generated by dividing striped hyena abundance by the effectively sampled area. The effective sample area includes a buffer around minimum convex polygon (MCP) that comes from outer camera trap stations. Buffer width is computed from half mean maximum distance moved (HMMDM) which was calculated from mean maximum distance moved (MMDM) of individual striped hyenas during the sample period.

$$\hat{W} = (\frac{\sum \hat{d} / \hat{n}}{2})$$

Where $\hat{W}$ is the resulting boundary strip width, $\hat{d}$ the maximum distance moved, and $\hat{n}$ the number of maximum distances compared. Then the boundary strip of width $\hat{W}$ (HMMDM) was added around the perimeter of the area covered by

camera traps (MCP), to obtain the effectively sampled area. The population density of striped hyena was estimate as:

$$\hat{D} = \frac{\hat{N}}{\hat{A}(\hat{W})}$$

Where $\hat{D}$ is the resulting hyena density, $\hat{N}$ the population size computed by CAPTURE, and $\hat{A}(\hat{W})$ the resulting effectively sampled area.

3.4 Results

A total 150 trap-nights of sampling effort was expended at each phase and with total 600 trap-nights from all four phase over six months from December 2007 to May 2008, and as a result 34 usable striped hyena photographs were obtained with average trapping effort of 17.6 trap nights per hyena photograph. Out of 60 grids, in 25 grids (41.6%) striped hyena was captured. Different individual hyenas were identified with the asymmetrical striped pattern of both the flank (Fig. 3.3). Out of 34 striped hyena photographs total 24 individual hyenas were identified out of them 17 individuals were captured once, 4 individuals were caught twice, and 3 were caught three times during the sampling period. Total number of individuals identified at each phase varied from 3 to 11, and the number of total capture and recaptures varied from 3 to 16. The capture histories of all the four phase camera trap survey were shown in table 3.1.

The model selection criteria of Program CAPTURE identified M_0 as the most appropriate model for three phases central, East, and NP, assumes no differences

in capture probability in between different individuals and sampling occasions and did not select any model for west phase due to lack of recaptures of camera trap survey of GNPS (Table 3.2). We consider jakknife model (M_h) for west phase that assumes heterogeneous hyena capture probability also model M_h had the second highest model selection criterion for other three phases. Results of the test for behaviour response, test for time specific variation in trapping probabilities and goodness-of-fit test of model M_h of programme CAPTURE in presented in table 3.3. Test for heterogeneity of trapping probability in population of null hypothesis of model M_0 vs. alternative hypothesis of model M_h was not performed as expected value were too small.

3.4.1 Estimates of effectively sampled area

The polygon formed by the outer most camera trap stations (MCP) measured for all the phases separately and buffer was added of HMMDM as described in methodology. Buffer width ($\hat{W}(S\hat{E}\hat{W})$) was estimated as 1.99 (0.59). For central it was 61.06 km² and with buffer an effectively sampled area ($\hat{A}$) of 132.37 km², for east 69.58 km² and with buffer 145.44 km², for NP 78.55 km² and with buffer 159.03 km², and for west 67.67 km² and with buffer 142.28 km². Table 3.4 summarises MCP, effectively sample area (MCP + buffer with HMMDM) and area with upper and lower SE and 95% confidence interval of effectively area sampled of all the phase sites of camera trap survey for striped hyena in GNPS (Appendix-I).

3.4.2 Estimates of striped hyena population and densities

Using the appropriate model M_0 given by program CAPTURE the average Capture probability ($\hat{P}$) per sample for central was 0.17 and corresponding population size estimate ($\hat{N}$) was 5 with a standard error ($S\hat{E}\hat{N}$) of 1.32, for east capture probability ($\hat{P}$) was 0.09 and corresponding population size estimate ($\hat{N}$) was 17 with a standard error ($S\hat{E}\hat{N}$) of 5.14, for NP capture probability ($\hat{P}$) was 0.05 and corresponding population size estimate ($\hat{N}$) was 12 with a standard error ($S\hat{E}\hat{N}$) of 8.81, for west was no result was given due lack of recaptures, but when considering jackknife estimator M_h where the average Capture probability ($\hat{P}$) per sample for west was 0.10 and corresponding population size estimate ($\hat{N}$) was 3 with a standard error ($S\hat{E}\hat{N}$) of 2.46.

Striped hyena density was obtained by dividing estimated population size ($\hat{N}$) by the effectively sampled area ($\hat{A}$). The estimated density ($\hat{D}$) for central was 3.78 striped hyena/100 km², for east 11.69 /100 km², for NP 7.55/100 km², and for west was 2.27/100 km². The density of striped hyena for the GNPS was calculated as (mean of estimated population size ($\hat{N}$)/ mean effectively sampled area ($\hat{A}$)) 6.50 striped hyena/100 km². TABLE 3.5 summarizes details of estimates of densities with model M_0 for central, east, NP and with model M_h for west phase study sites and their variations according to effectively sampled area of camera trap survey for striped hyena in GNPS.

TABLE 3.1: Capture histories of individual striped hyena photograph of all the four zones or study sites in GNPS, Western India, on 10 sampling occasions

Individual identification number	1	2	3	4	5	6	7	8	9	10
HYC-1	0	0	0	1	0	0	1	0	0	1
HYC-2	1	0	0	1	0	0	0	0	0	0
HYC-3	0	0	1	0	0	0	0	0	0	0
HYC-4	0	0	0	0	0	0	1	0	0	0
HYC-5	0	0	0	0	0	0	1	0	0	1
HYE-1	0	0	0	1	0	0	0	1	0	0
HYE-2	0	0	0	1	0	0	0	0	0	0
HYE-3	0	0	0	0	0	0	1	0	0	0
HYE-4	0	0	0	0	0	0	1	0	0	0
HYE-5	0	0	1	0	0	0	0	0	0	0
HYE-6	0	0	0	0	0	1	0	0	0	0
HYE-7	0	1	0	0	0	0	1	0	1	0
HYE-8	0	1	0	1	0	0	0	1	0	0
HYE-9	0	0	0	0	0	1	0	0	0	0
HYE-10	0	0	0	0	0	1	0	0	0	0
HYE-11	0	0	0	0	0	0	0	0	1	0
HYN-1	0	0	0	0	0	1	0	0	0	0
HYN-2	1	0	0	0	1	0	0	0	0	0
HYN-3	1	0	0	0	0	0	0	0	0	0
HYN-4	0	0	0	1	0	0	0	0	0	0
HYN-5	0	0	0	0	0	0	0	0	1	0
HYW-1	1	0	0	0	0	0	0	0	0	0
HYW-2	0	0	0	0	0	0	0	0	0	1
HYW-3	1	0	0	0	0	0	0	0	0	0

TABLE 3.2: The overall model selection test in CAPTURE scored the competing models of all the camera trap survey zones in GNPS excluding west zone where not a single individual was recaptured.

Zones	M_0	M_h	M_b	M_{bh}	M_t	M_{th}	M_{tb}	M_{tbh}
Central	1.00	0.97	0.41	0.62	0.00	0.30	0.47	0.66
East	1.00	0.85	0.31	0.53	0.00	0.15	0.35	0.58
NP	1.00	0.88	0.56	0.84	0.00	0.49	0.46	0.83

TABLE 3.3: Results of the test for behaviour response after initial capture (null hypothesis of model M_0 vs. alternate hypothesis of model M_b), test for time specific variation in trapping probabilities (null hypothesis of model M_0 vs. alternate hypothesis of model M_t), and goodness-of-fit test of model M_h of programme CAPTURE.

Zones	M_0 vs. M_b			M_0 vs. M_t			M_h goodness-of-fit		
	X^2	df	*P*	X^2	df	*P*	X^2	df	*P*
Central	0.28	1	0.60	2.78	9	0.97	13.18	9	0.13
East	0.01	1	0.93	2.29	9	0.99	9.97	9	0.35
NP	1.86	1	0.17	0.55	9	0.99	7.62	1	0.57

TABLE 3.4: Summarized details of estimates of area for all the four zones of camera trap survey for striped hyena in GNPS.

Zones	Area with camera traps (km^2)	Effective area (A) (km^2)	A with large SE (km^2)	A with small SE (km^2)	A with large 95% CI (km^2)	A with small 95% CI (km^2)
Central	61.06	132.37	158.09	108.81	184.88	88.17
East	69.58	145.44	172.50	120.54	200.58	98.61
NP	78.55	159.03	187.45	132.77	216.84	109.54
West	61.56	132.29	157.84	108.90	184.47	88.43

TABLE 3.5: Summarized details of estimates of densities with model M_0 of all the four zones study sites and for mean of camera trap survey for striped hyena in GNPS.

Zones	Density in effective sampled area		Density in area with large SE	Density in area with small SE	Density in area with large 95% CI	Density in area with small 95% CI	Density in 100 km^2
	N	*SE(N)*					
Central	5	1.32	5.80	2.33	8.59	1.31	3.78
East	17	5.14	18.36	6.88	27.45	3.46	11.69
NP	12	8.81	15.67	1.70	26.71	-2.43	7.55
West	3	0.00	2.75	1.90	3.39	1.63	2.27
Mean	9	5.09	12.17	2.46	14.90	2.12	6.50

Fig. 3.1: A typical foot print fore and hind limbs of striped hyena on sand in GNPS, note the size difference between them (A). Camera-trap survey of striped hyena in progress in GNPS (B).

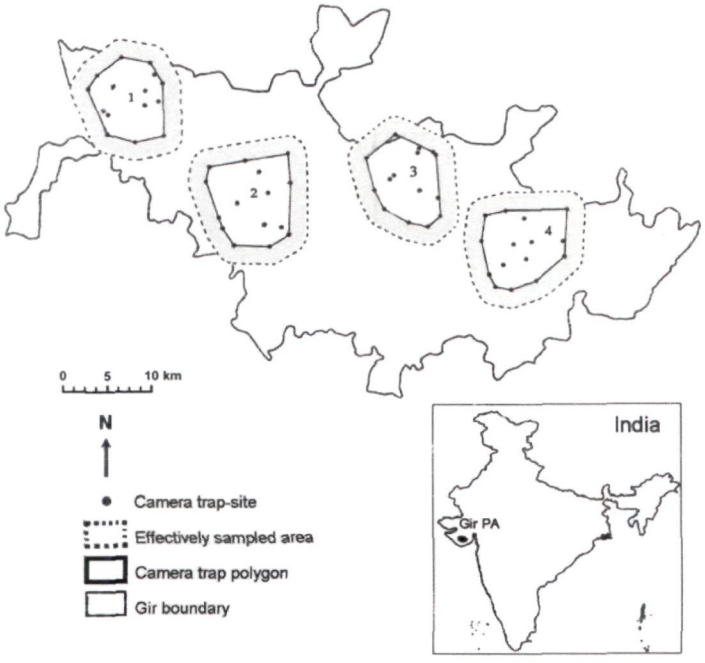

Fig. 3.2: Location of camera-trap stations in all the four zones (1-west, 2-NP, 3-central, and 4-east), minimum convex polygon (MCP) and effectively sampled area in the GNPS.

Fig. 3.3: Example of the asymmetry of striped pattern on two flanks of the same striped hyena HYC-4 (a and b), and example of unambiguous identification of the same striped hyena HYC-5 (c and d).

3.5 Discussion

We attempted to estimate striped hyena density in GNPS, a semi-arid forest ecosystem in India. We expected that striped hyena is equally distributed in GNPS. We found that striped hyena is present in almost entire GNPS, but the variation was observed in different zones. Here the question arises that, why the striped hyena density vary in different zones of GNPS? The variation in the striped hyena density in different zones could represent the relation with habitat. As in GNPS habitat changes from Teak (*Tectona grandis*) dominated dense forest in western part to more arid and open type scrub land in eastern part. Generally striped hyena favours open or thorn bush country in arid to semi-arid environments (Prater, 1971; Rosevear, 1974; Kruuk, 1976; Rieger, 1978; Leakey et al., 1999; Wagner, 2006). Gir east sanctuary is more open with thorn bushy and less vegetation density and high grass cover, where we found high striped hyena density, compare to west sanctuary which has dense vegetation cover. Also the result of striped hyena-habitat relationship study in GNPS suggests that striped hyena population was found positively correlated with the grass availability and negatively correlated with the tree density (M.S. Alam, unpublished data). The other reason for having high density in eastern part of GNPS could be the more number of nesses, human settlements and livestock availability. Striped hyena may remain active in areas frequented by humans, while avoiding them on a temporal scale (Rosevear, 1974; Kruuk, 1976; Wagner, 2006). The availability of safe refuge with human and livestock presence (alternative food from the carcass by natural causes and predators) may govern the population of hyena. This

estimate is higher than in most other distribution ranges and indicates GNPS as an important area for protecting striped hyena in India.

The mean density of striped hyena 6.50/100 km^2 is much higher than the only quantitative estimate of striped hyena density in the Serengeti National Park, Tanzania, Africa where, density was estimated as 2 striped hyena/100 km^2 (Kruuk, 1976) and from a large study in Laikipia District, Central Kenya as 3 striped hyena/100 km^2 (Wagner, 2006). The abundance of prey species is a determining factor for the abundance of large predators (Karanth and Nichols, 1998; Karanth et al., 2004) that also could determine the population of natural scavengers. There could be some reason to have this density in GNPS as compare to other studies that the availability of carcass by having a good density of prey population (Khan et al., 1996) and natural predators in this protected area. GNPS is one of the well protected forests in India, falls in semi-arid zone of Gujarat state, having open and thorn forest that provide favourable resources for the survival and protected, undulating and safe denning refuge for the shelter for striped hyena. This population estimate is higher than in other distribution ranges of this species and indicates GNPS as an important reserve for protecting striped hyena in India.

This study is the first to use the photographic capture-recapture sampling technique for estimating abundance of wild population in GNPS. Confirming the previous research using photographic capture-recapture technique with other

species (Karanth, 1995; Karanth and Nichols, 1998; Karanth et al., 2002; Azlan and Sharma, 2003; Silver et al. 2004; Trolle and Kery, 2005), this study demonstrate the viability of the method for estimating densities of individually recognizable species that have been usually difficult to study because of cryptic habitats, large home range, and low population densities. In GNPS photographic capture-recapture sampling for the secretive species was found suitable, as our camera traps suffered least damage by animals (only one case where one striped hyena had taken away the one camera trap unit on a hillock) than other camera trap study (Karanth and Nichols, 1998), and no theft or vandalism by human, but it is necessary to use some protective structure like chain-lock system for the camera traps (easy with Camtrakker units). Despite of some methodological short coming of this study, largely due to time, recourse constraints and less number of camera trap units we found, photographic capture-recapture method was successfully applied to assess the status of striped hyena more rigorously then had been possible earlier. Further refinement to the methodology and its application would make this method even more useful for monitoring the status of this elusive species.

CHAPTER-4

FOOD HABITS

4.1 Introduction

Top predators are ecosystem's key species. They are often relatively scarce, can predate upon herbivores and other carnivores and, are dietary and habitat specialist species (Ruiz-Olmo and Jimenez, 2009). The carnivores are a fascinating group (Gittleman and Harvey, 1982; Gittleman, 1989) secondary consumers in a food chain and feed on herbivores. Tertiary and other high order consumers that feed on secondary consumers are also carnivores (Verma and Agrawal, 1974). The food habits of the animals determine a number of life history strategies like habitat selection, movement and success in reproduction (Krebs, 1972). Hyenas are carnivore and scavenger by habit (Prater, 1971; Kruuk, 1975; Kruuk, 1976; Macdonald, 1984; Boitani and Bartoli, 1986; Hofer, 1998; Menon, 2003). The peculiar structural characteristics of hyena fit for its particular mode of life, which is to feed on prey killed by other animals (Prater, 1971). The striped hyena (*Hyaena hyaena*) is classic scavenger, existing around human settlements and feeds on dried bones, carcasses and also on fruits, insects and reptiles (Kruuk, 1975; Kruuk, 1976; Hofer, 1998). Very little studies on striped hyena have been done. According to Kruuk (1976), striped hyena is more omnivorous than spotted hyenas, scavenging at great deal and consumes a variety of food items.

The striped hyena is also known for occasional killing of livestock or even people (Prater, 1971; Kruuk, 1976; Hofer, 1998). There are records of attacks by striped hyena on sheep, goat and donkey from North Africa, Israel, Iran, Pakistan and India, on horse in Iran and on dog in India (Hofer, 1998). In India, Sholapur (Maharashtra), at one den of striped hyena, carcasses of sheep, goat, buffalo, cow, domestic cat and dogs were observed (Bilal Habib Pers. Comm.). In many areas of their geographical distribution, there are documented cases of injuries to adults sleeping outside, snatching and killing of children (East and Hofer, 1998) and grave robbery (Kruuk, 1976; East and Hofer, 1998). Striped hyena also occasionally cause damage to date palms in date plantation (Hofer, 1998), fields of melons, water melons, grapes, apricots, peaches and cucumber and around the settlements in Serengeti where often seen to feed on domestic refuse such as fruits of various kinds, bread, boiled potatoes and any animal offal such as bones, pieces of leather, etc. (Kruuk, 1976).

All in all as a scavenger the striped hyena is useful animal, helping to keep the environment clean (Prater, 1971), and sanitizing the ecosystem and recycling the precious inorganic nutrients like calcium and phosphorus locked up in carcasses of dead animals by chewing up even the large bones using their specially adapted molars.

In Gir National Park and Sanctuary (GNPS), there is a competition for carcasses between the predators itself (lion and leopard) and with the natural scavengers like

striped hyena. GNPS supports a good population of herbivores (Khan et al., 1996), and livestock. According to Kamboj et al. (1997), Gir with its 54 Maldhari Nesses supports 10,000 livestock and also a large number of villages around and nearby the protected area. The purpose of this study was to investigate the food habits, trend in herbivore biomass utilization and preference etc. by striped hyena a scavenger coexisting with two big cats in the GNPS.

4.2 Methodology

It is difficult to determine each prey item contributing to the diet of a carnivore species by direct observations in the field. Scat analysis is thus widely used for studying food habits of carnivores because it is non-invasive technique and scats are easy to collect and analyze (Korschgen, 1980; Litavaitis et al., 1996). Thus scat analysis method was used to determine the food habits of striped hyena in GNPS. There were some problems such as lack of information on minimum hairs to be examined per scat and minimum number of scats required for an accurate estimate of the diet of striped hyena.

Striped hyena scats are very easy to identify, as they are white pallet like structure resembles to camel dung (Kruk, 1975; Jhala, 2002). Adult hyenas scat is bigger in size and white in colour (Fig. 4.15), while young ones scats are smaller in size and darker in colour. Scats were collected in polybags, food remains near the den were noted and regurgitated hairballs found near the dens were also collected and tagged with information like place and date of collection. The scats were collected

randomly from October 2006 to June2009. Each scat was crushed very carefully avoiding any mix-up and indigestible prey remains such as hairs, bones, claws, hooves, teeth, feathers and other materials were used for identification of prey species (Lockic, 1959; Korschgen, 1980; Jhala, 1993; Mukherjee et al., 1994a and b; Litvaitis et al., 1996; Jethva and Jhala, 2003). The hairs are the most important factor used to determine the prey species in the scats (Maurya, 2005). Hairs are collected randomly from each scat and treated with the xylol and subsequently with xylene.

For the standardisation of minimum number of hairs to be examined per scat, 51 scats were selected randomly from the overall scats collected (n=367) at random from all over GNPS during 2006-2007. And from each scat 51 hair were taken randomly for microscopic examination using a compound stereoscopic microscope (Olympus CH 20i) under 40X magnification. Rest of the scats were analysed according to result of standardisation. Regurgitated hairballs were analyzed same way as scats were. The microscopic examination of hairs and their characteristics such as medullary and cuticular patterns were observed and compared with the reference slides. The reference slides of all possible prey species found in the study area were prepared. The hair samples were collected from the study area as well as from Sakkarbag Zoo, Junagardh, for comparison as well as for making reference slides.

4.3 Data analysis

To determine the minimum hairs to be examined per scat, cumulative percent of occurrence was computed. As a sample total 51 randomly collected scats were scanned. The proportion of prey species detected by scanning each hair was calculated for every additional hair. The cumulative proportions of prey species detected from a scat were calculated for all the hair analyzed and plotted against the number of hair scanned and ninety five percent lower bounds for all the cumulative proportion were computed (Mukherjee et al., 1994a; Jethva and Jhala, 2003).

For the standardisation of minimum number of scats needed to be analysed to detect all possible prey items in the diet of striped hyena, 100 scats were selected randomly irrespective to season and habitat from the overall scats collected (n=367) at random from all over GNPS during 2006-2007.

Percentage occurrence of a mammalian prey item was calculated as the number of times a specific prey item was found to occur in scat and expressed as a percentage of all prey occurrences (Ackerman et al., 1984; Floyed et al., 1978; Weaver et al., 1979). The frequency of occurrence of prey species in the scats was computed as the number of occurrence of each prey type divided by the total number of scat analyzed and expressed as percentage (Leoplod and Karusman, 1986; Corbet, 1989; Reynold and Aebischer, 1991; Jethva and Jhala, 2004). Diet content other than mammalian prey were also calculated as number of times a

specific item was found to occur in scat and expressed as a percentage of occurrences of all items other than mammalian prey.

To account seasonal variations, a total of 690 striped hyena scats were analysed, collected between 2006-2009, from all over the GNPS. Out of that 284 scats were of three winters (2006-2007, 2007-2008 and 2008-2009) while 406 scats were of three summers (2007, 2008 and 2009). Seasonal variation in diet was computed by analysing scats of winter and summer separately and represented as percentage occurrence. Chi-square values following Fowler and Cohen (1986) were computed to observe the difference between seasonal diets. Seasonal variation in diet items other than mammalian prey were also analysed as mammalian prey items were analysed.

Four different clans namely Khada clan, Kasia clan, Biliat clan and Tulsishyam clan were monitored on regular basis and their scats were collected and marked. To find the diet variation of striped hyena between different clans scats collected from different clans were analysed separately.

To observe the hyena food habit in different management unit of GNPS, scats collected were separated in to three zones as West Gir, Central Gir and East Gir, analysed and represented accordingly. Also, to find any difference in striped hyena diet between different zones, chi square test was performed.

Biomass of prey ingested (Floyd et al., 1978) was calculated by estimating the weight of prey eaten per scat sample (Y) for each prey type using the equation: Y=0.38+0.02X, where X is the mean adult weight of a given prey type. The average body weight of each prey species required for biomass estimation was taken from available literature (Schaller, 1967; Prater, 1971; Karanth and Sunquist, 1995).

4.4 Results

Analysis of 699 striped hyena scats from GNPS showed that 12.92% scats were found to have single mammalian prey item, while only 0.43% scats were found with five prey items (Fig. 4.1). Analysis of 51 randomly selected scats from 367 scats of annual collection showed that the minimum number of mammalian hair to be examined per scat to detect all mammalian prey species in a particular scat with 95% certainty was 21 hairs (Fig. 4.2).

A variety of food items were identified in the diet of striped hyena in GNPS, including large mammals to small rodents, birds, insects and even fruits. Total 12 mammalian prey species were detected. Considering the mammalian prey items chital was found to be the most common prey item in the diet of striped hyena with percentage of occurrence 32.32 ± 1.53 (with 95% confidence limit), hare 24.72 ± 1.16, buffalo 15.20 ± 0.70, sambar 12.27 ± 0.56, cattle 7.24 ± 0.32, squirrel 3.11 ± 0.12, rodent 1.68 ± 0.05, langur 1.32 ± 0.03, wildboar 1.08 ± 0.01, civet 0.96 ± 0.00, bluebull 0.06 ± 0.00, and dog 0.06 ± 0.00 (Fig. 4.3). *Zizyphus*

spp. was found as most common non mammalian prey in striped hyena diet. Non mammalian prey found in diet are represented in Fig. 4.4.

Occasionally in East Gir sanctuary striped hyena was (n=28) observed to search in human wastage near a temple inside the forest and often seen feeding on domestic refuse such as bread, fruits, pulses, and sweets. Table 4.1 list the contents of 583 scats and regurgitated hair-balls of striped hyena collected, and food remains recorded near den sites from GNPS.

Seasonal variation in the diet of striped hyena was computed by analysing two winters and two summer's scats. Result showed that there is variation in the diet of winter and summer in mammalian prey in striped hyena diet (Fig. 4.5) and non-mammalian prey (Fig. 4.6). According to result of chi-square test, significant difference was found in chital, sambar, buffalo, birds, and fruits. Table 4.2 showing percentage occurrence of winter and summer diet including all contents with chi-square values. Annual variation in mammalian prey item in striped hyena diet is shown in Fig. 4.9.

Figure 4.7 and 4.8 represents the variation in the mammalian and non-mammalian food items respectively, prey items in the diffrent striped hyena clan's diet. Results of different clans of striped hyena and different zones of GNPS are presented in table 4.4 and table 4.5, respectively. Between the clans diet significant difference were found in cattle ($P < 0.01$), squirrel ($P < 0.01$) and

langur ($P < 0.01$) only, while at zone level difference were found in hare ($P < 0.05$), cattle ($P < 0.01$) and langur ($P < 0.05$). Figure 4.11 and 4.12 shows the variation in the percentage occurrence and relative biomass repectively of mammalian prey items in the striped hyena diet.

The 'Observation area-curve' (Odum et al., 1955; Mukhergee et al., 1994a) was used to estimate the minimum number of scats that need to be analysed and examined for a reliable estimate of mammalian prey species of striped hyena's diet in GNPS. The percent occurrence of each species was calculate in increment of 10 scats, from 10 to 100. The 'Observation area-curve' shows that the all striped hyena prey species could be detected by analysing 40 scats (Table 4.3).

Total prey biomass consumed by the striped hyena in GNPS was 3668.58 kg from April 2006 to July 2009. Analysis of annual relative biomass consumed in three consecutive years (Fig 4.10) showed that in 2006-2007 wild biomass contribution was 42.92% and livestock was 57.67%, in 2007-2008 wild biomass was 48.08% and livestock was 51.91% and in 2008-2009 wild biomass contribution in striped hyena diet was 61.73% while livestock was 38.27% (Fig. 4.13). Also variation was observed in the contribution of precentage relative biomass of wild mammalian prey and domestic mammalian prey in the striped hyena diet observed in different zones of GNPS (Fig. 4.14). On average 50.91% of total relative consumed biomass was contributed by the wild prey while livestock contribution

was found as 49.08%. Prey biomass contributed by different prey species contributed in the diet of striped hyena is summarized in table 4.6.

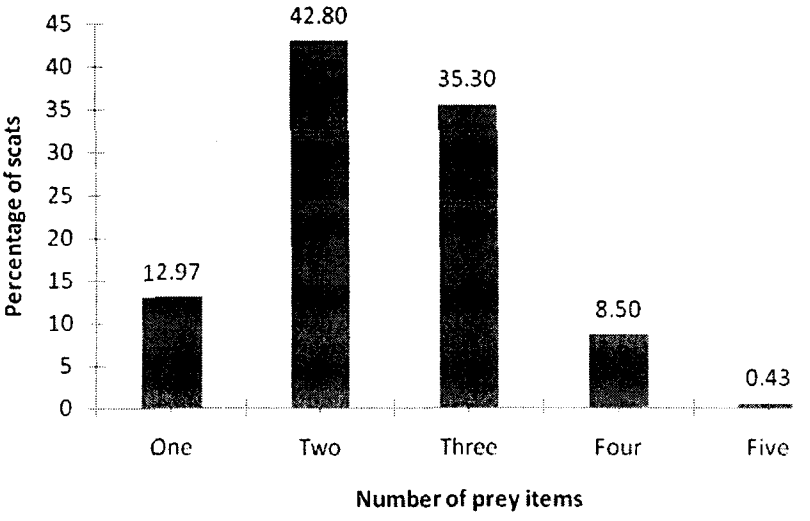

Fig. 4.1: Percentage occurrence of mammalian prey items of striped hyena scats with 95% CL (n =699).

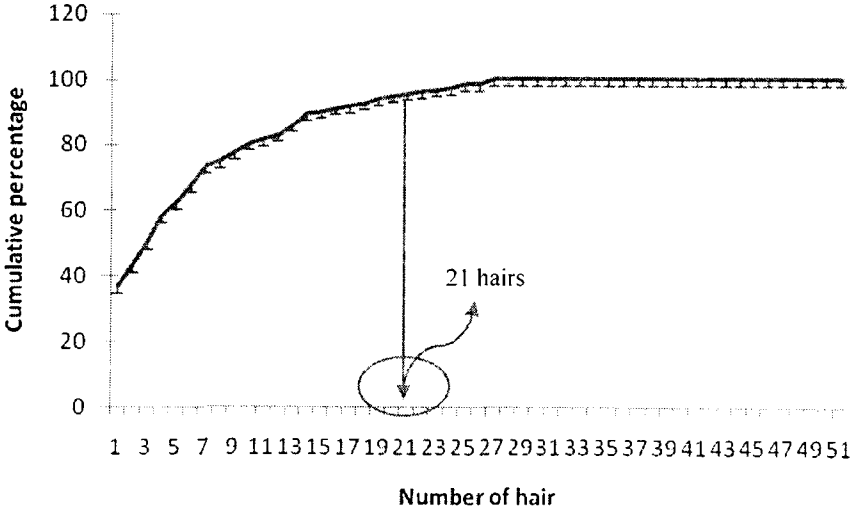

Fig. 4.2: Number of hairs examined for each scat verses cumulative percentage of prey items detected in striped hyena scats in GNPS. Error bars represent 95% lower bounds (n=51).

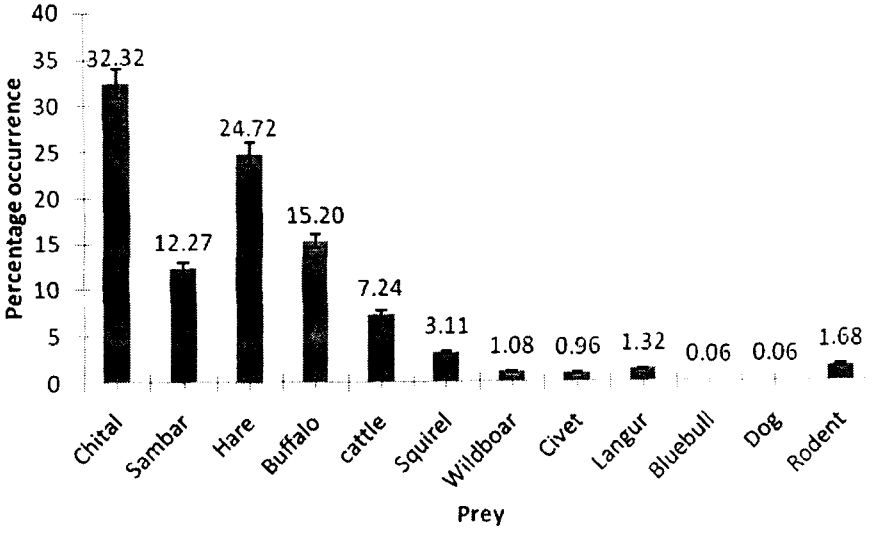

Fig. 4.3: Percentage occurrence of mammalian prey items found in striped hyena scats with 95% confidence limit (n =699).

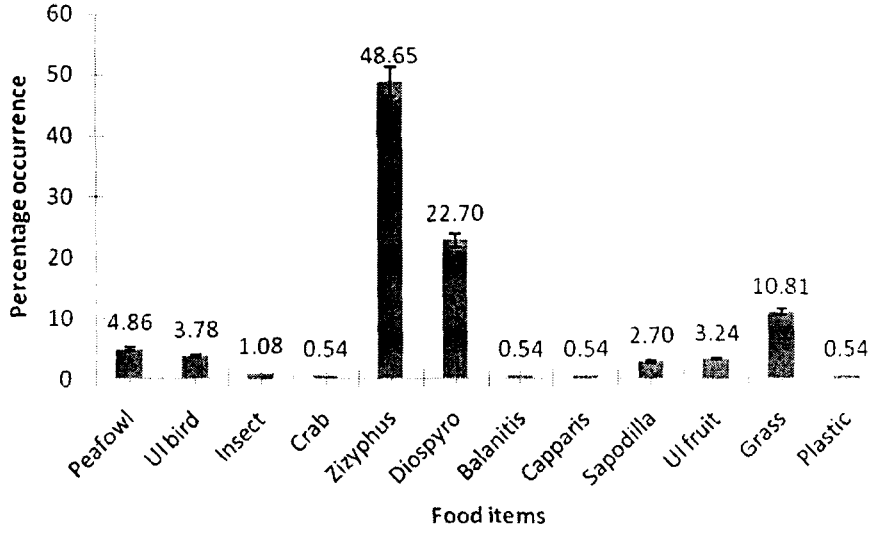

Fig. 4.4: Percentage occurrence of non-mammalian prey items found in striped hyena scats with 95% confidence limit (n =699).

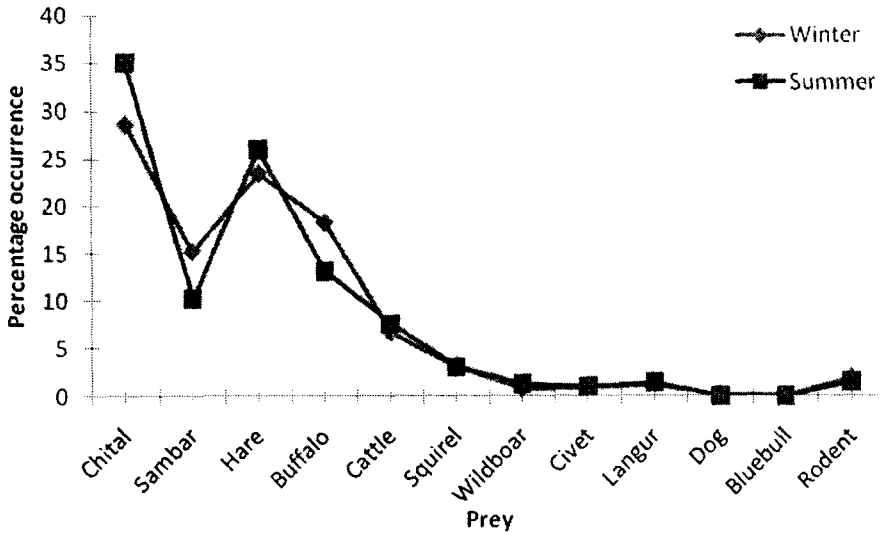

Fig. 4.5: Seasonal variation in winter season and summer season in the striped hyena's diet.

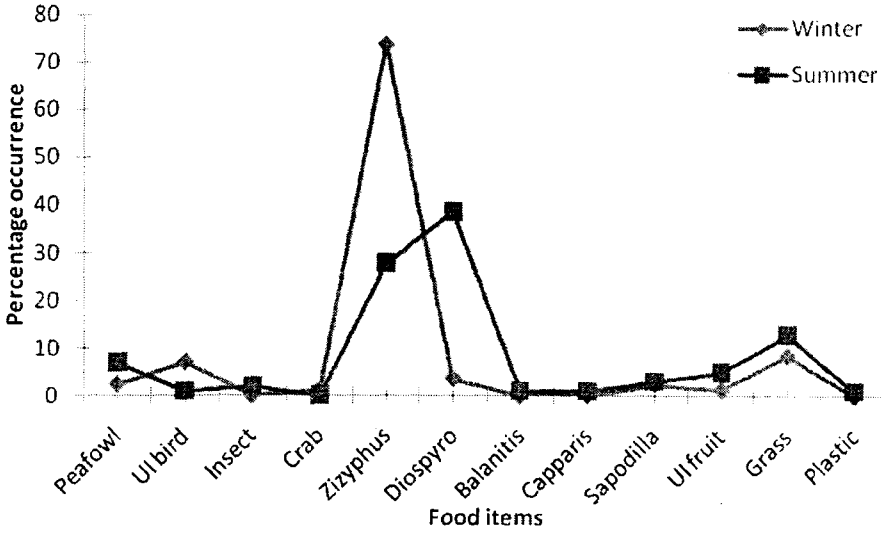

Fig. 4.6: Seasonal variation in non-mammalian content in winter season and summer season in the striped hyena's diet.

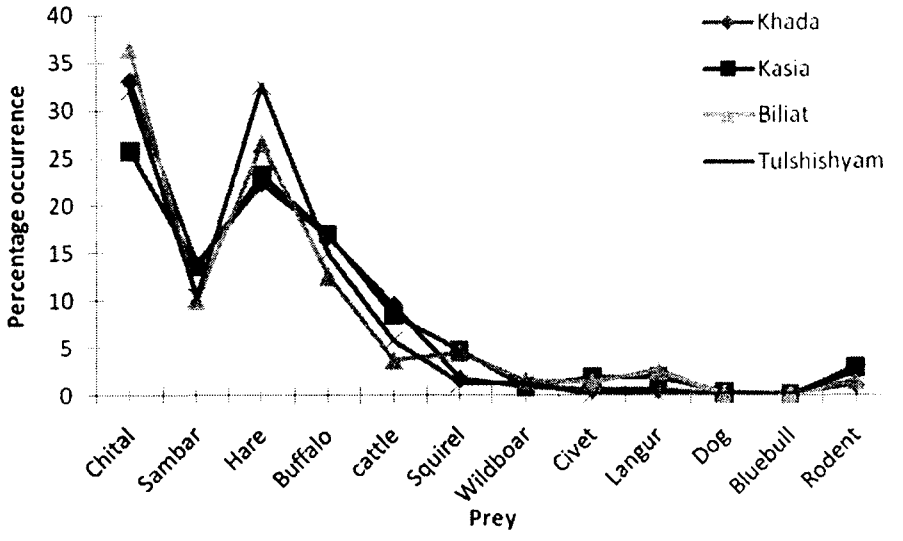

Fig. 4.7: Variation in the of mammalian prey items in the diffrent striped hyena clan's diet.

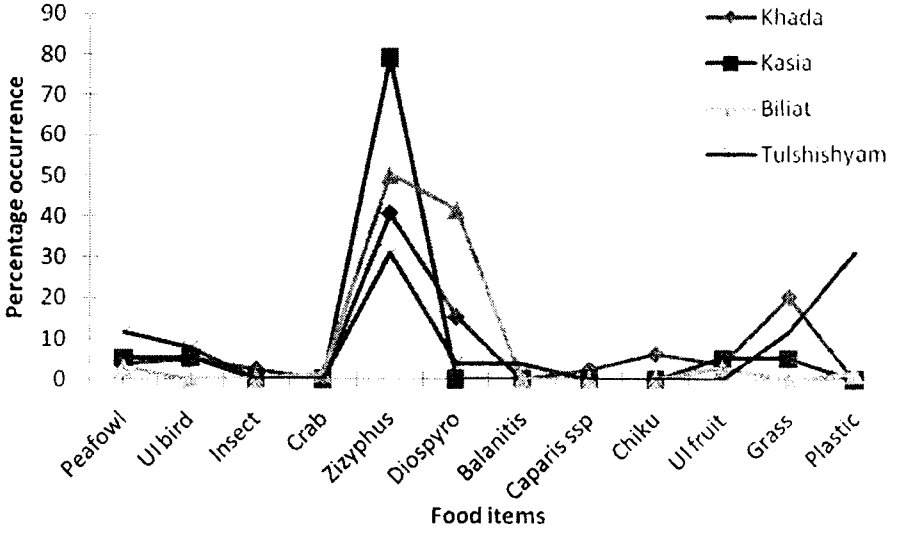

Fig. 4.8: Variation in the non-mammalian prey items in the diffrent striped hyena clan's diet.

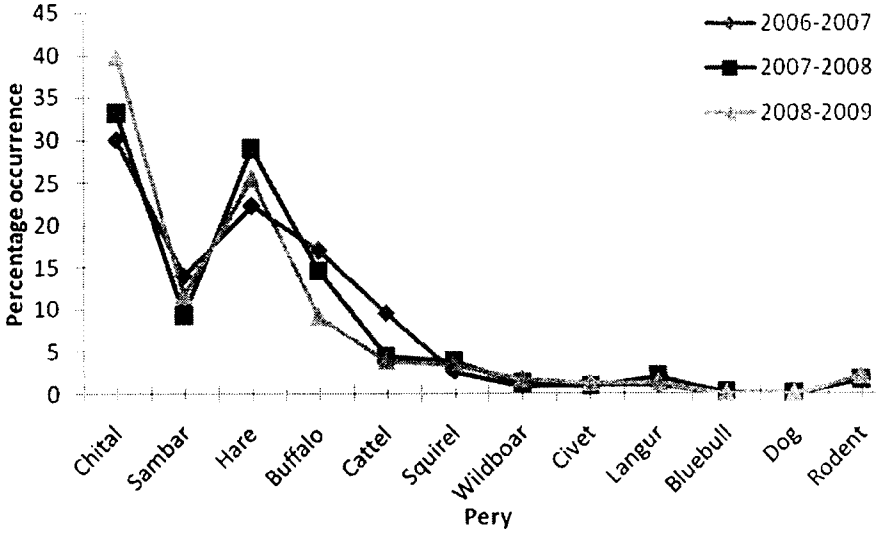

Fig. 4.9: Annual variation in diet of the striped hyena diet found in GNPS. Data from three years between 2006 to 2009. Graph shows that there is a decrease in %age occurrence of livstock and increase in majore wild prey.

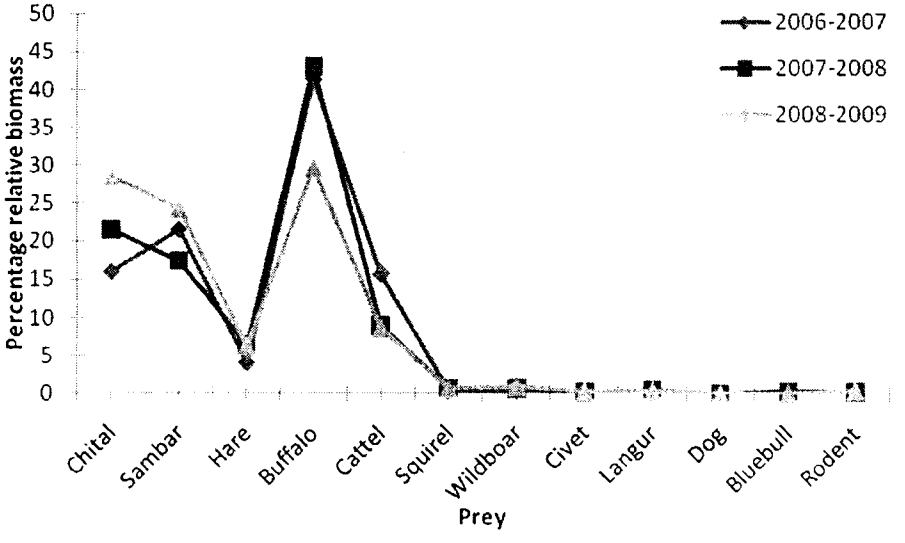

Fig. 4.10: Annual variation in the contribution of precentage relative biomass of mammalian prey in the striped hyena diet.

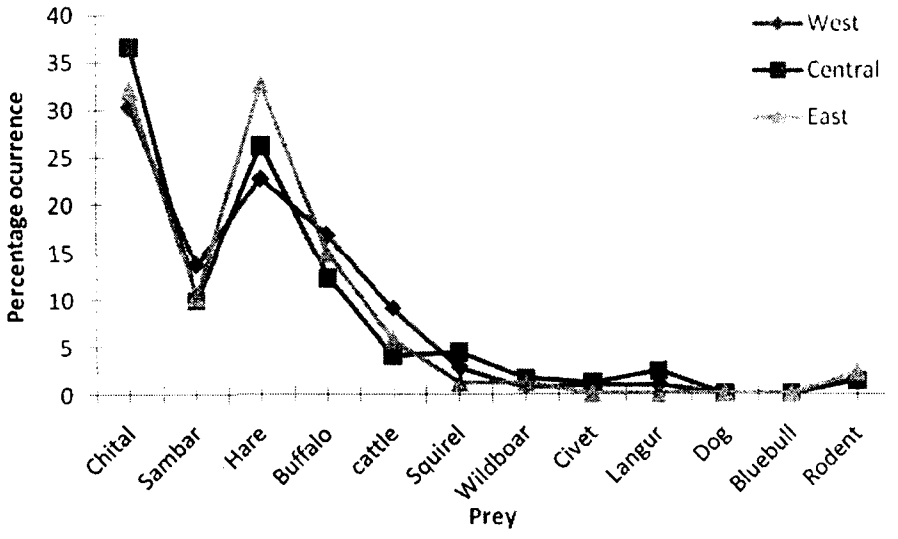

Fig. 4.11: Variation in the percentage occurrence of mammalian prey items in the striped hyena diet observed in different zones of GNPS.

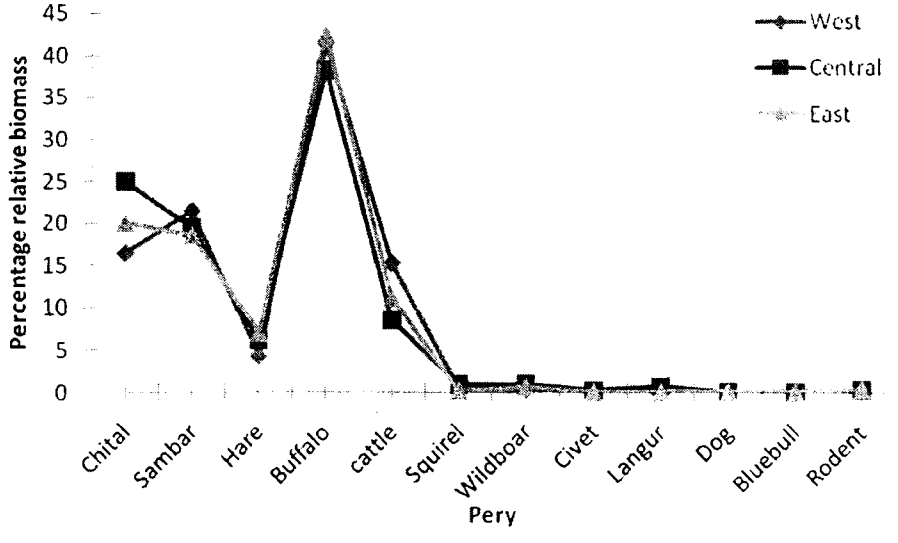

Fig. 4.12: Variation in the contribution of precentage relative biomass of mammalian prey items in the striped hyena diet observed in different zones of GNPS.

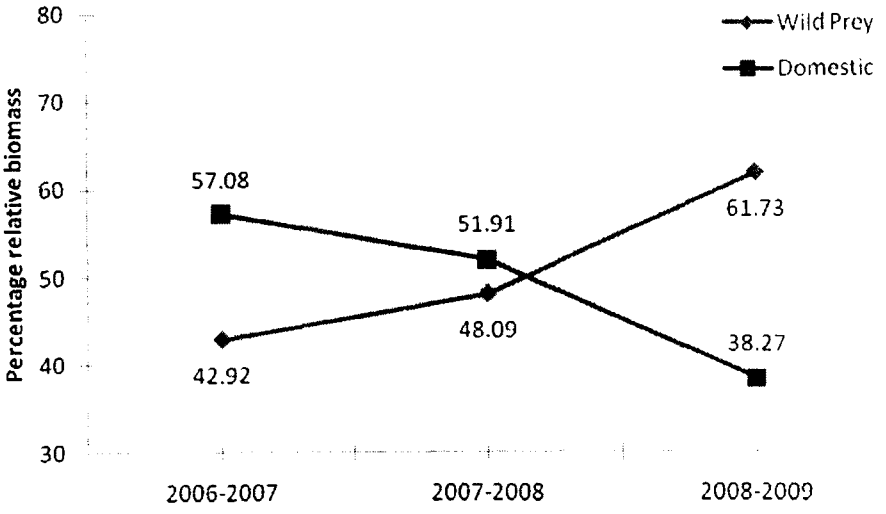

Fig. 4.13: Annual variation in the contribution of precentage relative biomass of wild mammalian prey and domestic mammalian prey in the striped hyena diet observed in GNPS. Data from April 2006 to July 2009.

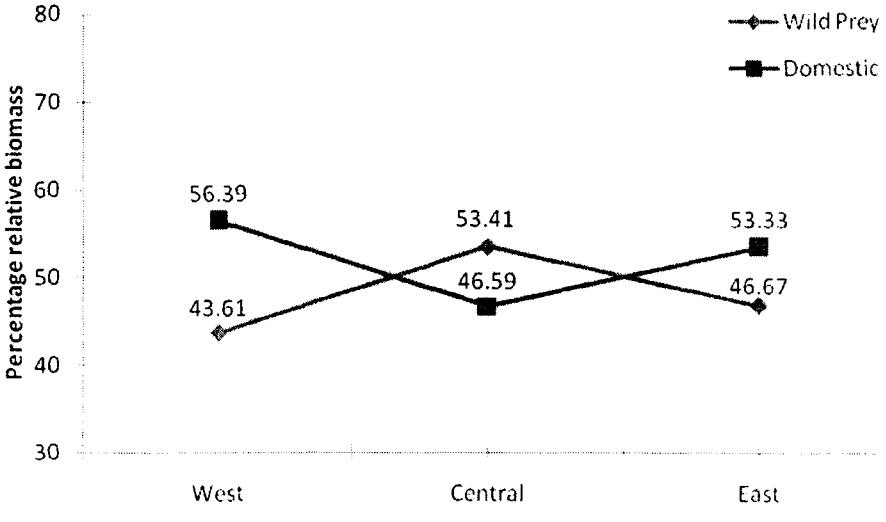

Fig. 4.14: Variation in the contribution of precentage relative biomass of wild mammalian prey and domestic mammalian prey in the striped hyena diet observed in different zones of GNPS. Data from April 2006 to July 2009.

Table 4.1: Contents in percentage of scats, regurgitated hair-ball, and food remains recorded near den site of striped hyena during 2006-2008 in GNPS.

Items	**% age of scats containing remains**	**% age regurgitated hair-ball**	**Food remains recorded at dens**
Chital	77.84	70	21
Sambar	31.53	0	4
Hare	61.72	75	1
Buffalo	40.97	60	10
Cow	19.21	0	4
Squirrel	8.55	20	-
Wildboar	2.40	0	1
Civet	2.23	0	-
Langur	3.26	10	1
Dog	0.17	0	-
Bluebull	0.17	0	1
Rodent	4.95	0	-
Porcupine	-	-	1
Leopard	-	-	1
Peafowl	2.54	0	11
UI Bird	1.20	0	1
Insect	0.34	0	-
Zizyphus	10.95	0	-
Diospyro	6.35	0	-
Balanitis	0.17	0	-
Capparis	0.17	0	-
Mngifera	-	-	1
UI fruit	1.69	0	-
Grass	4.60	0	-
Plastic material	1.37	0	-
Total			58

Table 4.2: Frequency of contents of winter scats (n=217) and summer scats (n=359) and their Chi-sq values of striped hyena collected from Gir national park and sanctuary, during 2006-2008.

Prey Items	***Winter***	***Summer***	**Chi-square**
Chital	134	311	10.84
Sambar	87	89	10.36
Hare	120	233	2.04
Buffalo	109	121	9.25
Cow	41	68	0.00
Squirrel	16	27	0.00
Wildboar	4	10	0.49
Civet	4	9	0.26
Langur	6	13	0.30
Dog	1	0	1.65
Bluebull	1	0	1.65
Rodent	11	12	1.01
Peafowl	2	7	0.92
UI Bird	6	1	6.88
Insect	0	2	1.21
Zizyphus	37	21	16.85
Diospyro	3	34	13.78
Balanitis	0	1	0.60
Capparis	0	1	0.60
UI fruit	1	3	0.27
Grass	7	13	0.06
Total	590	976	

Table 4.3: Percentage occurrence of prey species in striped hyena scats seen through increment of 10 scats in Gir national park and sanctuary, Gujarat, India.

No. of scats	Chital	Sambar	Hare	Buffalo	Cow	Squirrel	Civet	Langur	Rodent
10	26.67	10.00	30.00	20.00	3.33	3.33	6.67	0.00	0.00
20	25.93	14.81	14.81	25.93	11.11	3.70	0.00	0.00	3.70
30	31.03	17.24	13.79	27.59	0.00	0.00	3.45	0.00	6.90
40	17.39	17.39	30.43	4.35	17.39	4.35	0.00	8.70	0.00
50	34.62	3.85	26.92	11.54	15.38	3.85	0.00	0.00	3.85
60	37.50	8.33	25.00	20.83	8.33	0.00	0.00	0.00	0.00
70	28.00	8.00	28.00	16.00	12.00	4.00	0.00	4.00	0.00
80	26.47	14.71	20.59	20.59	8.82	2.94	2.94	0.00	2.94
90	40.91	4.55	27.27	13.64	13.64	0.00	0.00	0.00	0.00
100	27.27	18.18	13.64	13.64	13.64	4.55	0.00	0.00	9.09

Table 4.4: Percentage occurrence of mammalian prey items found in the scats of different striped hyena clans with confidence interval from Gir National Park and Sanctuary, Gujarat, India. Scats were collected from April 2006 to July 2009. Chi square values represented here to observe the difference level in the diet between different clans.

Prey species	Khada Clan %age occurrence ± confidence interval	Kasia Clan %age occurrence ± confidence interval	Biliat Clan %age occurrence ± confidence interval	Tulsishyam Clan %age occurrence ± confidence interval	Chi sq values
Chital	33.12 ± 2.58	25.78 ± 2.53	36.42 ± 3.23	32.00 ± 4.67	7.69
Sambar	13.87 ± 1.06	13.54 ± 1.3	9.89 ± 0.84	10.29 ± 1.45	4.53
Hare	22.35 ± 1.73	23.18 ± 2.27	26.53 ± 2.34	32.57 ± 4.75	6.72
Buffalo	16.64 ± 1.28	16.93 ± 1.64	12.42 ± 1.07	14.86 ± 2.13	3.98
Cattle	9.46 ± 0.71	8.33 ± 0.78	3.58 ± 0.27	5.71 ± 0.77	14.40, $P < 0.01$
Squirel	1.63 ± 0.08	4.69 ± 0.42	4.42 ± 0.35	1.14 ± 0.06	12.24, $P < 0.01$
Wildboar	0.82 ± 0.00	0.78 ± 0.0	1.47 ± 0.08	1.14 ± 0.06	1.43
Civet	0.49 ± 0.00	1.82 ± 0.12	1.26 ± 0.05	0.00 ± 0.0	6.45
Langur	0.49 ± 0.00	1.82 ± 0.12	2.53 ± 0.18	0.00 ± 0.0	11.35, $P < 0.01$
Dog	0.00 ± 0.00	0.26 ± 0.0	0.00 ± 0.0	0.00 ± 0.0	3.29
Bluebull	0.16 ± 0.00	0.00 ± 0.0	0.00 ± 0.0	0.00 ± 0.0	1.69
Rodent	0.98 ± 0.00	2.86 ± 0.23	1.47 ± 0.08	2.29 ± 0.25	5.44

Table 4.5: Percentage occurrence of mammalian prey items of found in the scats of striped hyena with confidence interval collected between April 2006 to July 2009 from different zones of Gir National Park and Sanctuary, Gujarat, India. Chi square values represented here to observe the difference level in the diet of different zones.

Prey species	**West Gir %age occurrence ± confidence interval**	**Central Gir %age occurrence ± confidence interval**	**East Gir %age occurrence ± confidence interval**	**Chi-squares Values**
Chital	30.29 ± 1.85	36.62 ± 3.18	32.00 ± 4.67	4.11
Sambar	13.74 ± 0.82	9.86 ± 0.82	10.29 ± 1.45	4.69
Hare	22.67 ± 1.38	26.16 ± 2.26	32.57 ± 4.75	6.47, $P < 0.05$
Buffalo	16.75 ± 1.01	12.27 ± 1.03	14.86 ± 2.13	4.38
Cattle	9.03 ± 0.53	4.02 ± 0.31	5.71 ± 0.77	12.14, $P < 0.01$
Squirel	2.81 ± 0.14	4.43 ± 0.34	1.14 ± 0.06	5.23
Wildboar	0.80 ± 0.0	1.61 ± 0.09	1.14 ± 0.06	2.01
Civet	1.00 ± 0.0	1.21 ± 0.04	0.00 ± 0.0	2.02
Langur	1.00 ± 0.0	2.41 ±0.16	0.00 ± 0.0	7.59, $P < 0.05$
Dog	0.10 ± 0.0	0.00 ± 0.0	0.00 ± 0.0	0.67
Bluebull	0.10 ± 0.0	0.00 ±0.0	0.00 ± 0.0	0.67
Rodent	1.71 ± 0.07	1.41 ±0.07	2.29 ± 0.25	0.60

Table 4.6: Frequency of occurrence of prey items in striped hyena scats (n=699) and contribution of different prey species in terms of biomass to striped hyena diet in Gir National Park and Sanctuary, between April 2006 and July 2009.

Prey species	Average Body Weight (X)	Frequency of Occurrence (F)	Percentage frequency	Weight of Prey eaten per Scat sample (Y)	Prey biomass Consumed (B)	% Relative biomass of Prey contribution
Chital	45.00	540	77.25	1.28	691.20	18.84
Sambar	166.00	205	29.33	3.70	758.50	20.68
Hare	3.00	413	59.08	0.44	181.72	4.95
Buffalo	273.00	254	36.34	5.84	1483.36	40.43
Cattle	180.00	121	17.31	3.98	481.58	13.13
Squirrel	0.11	52	7.44	0.38	19.88	0.54
Wildboar	32.00	18	2.58	1.02	18.36	0.50
Civet	2.00	16	2.29	0.42	6.72	0.18
Langur	8.00	22	3.15	0.54	11.88	0.32
Dog	12.00	1	0.14	0.62	0.62	0.02
Bluebull	184.00	1	0.14	4.06	4.06	0.11
Rodent	0.11	28	4.01	0.38	10.70	0.29

X=average body weight of an individual prey type in kg.
Y=0.38+0.02X
B=F×Y
Total prey biomass consumed = 3668.58 kg.
Total number of scats = 699

Fig. 4.15: A typical scat-A, collected scats in poly-bags (B), food remains near den-C, d & E, a adult male sambar killed by lions (F) and Indian hare most abundant small mammalian prey in striped hyena diet (G) in GNPS.

Fig. 4.16: A- Fruits of Timbru (*Diospyros melanoxylo*) and B- Bor (*Zizyphus ssp.*). These two fruits are eaten by striped hyena in GNPS in their respective seasons, and found difference at significant level in the seasonal diet variation.

4.5 DISCUSSION:

Food habit is one of the important aspects of the animal ecology. The striped hyena is one of the large carnivores and scavengers, but very little is known about its feeding ecology. The striped hyena is a scavenger (Prater, 1971; Kruuk, 1975; Kruuk, 1976; Macdonald, 1984; Boitani and Bartoli, 1986; Hofer, 1998; Jhala 2002; Sinha, 2004); feeds on prey killed by the other animals. According to Kruuk (1976), striped hyena is an omnivore which feed on a variety of food items from mammals, birds, and insects to vegetable material.

The present study indicated that 12.07% striped hyena scats represented Single mammalian prey item, 38.79% represented two, 38.62% represented three, 10% represented four, and only 0.52% represented five prey items. The variation in diet of striped hyena from single to five prey items per scat can be attributed to its scavenging habit which is supplemented by small mammals, insects, birds, and vegetable materials, that makes the striped hyena a generalistic feeder. Also minimum number of hair to be examined per scat which was found to be 21 (with 95% Confidence limit) in striped hyena scat (higher than other natural predators of GNPS, Mukhergee et al., 1994a), suggest variation of content from scat to scats.

The diet composition of striped hyena in GNPS is not restricted to any specific material but comprised on a range of different constituents from wild species (e.g. chital, sambar) to domesticated animal (e.g. buffalo, cow) and even small mammalian (e.g. hare, squirrel), birds (e.g. peafowl) to plant material and fruits (e.g. *Diospyro, Zizyphus*). This high range of variability in the diet composition

has also been reported by Kruuk (1976) and Wagner (2006) in Serengeti and Kenya respectively.

Nevertheless, there is a small preference in accordance to availability, to chital followed by buffalo and sambar. This is more appropriately being associable to the preference of the large natural predators of the GNPS. Because more availability of these prey items could be result of high predation by large carnivores on them, which has been established by Mukhargee (1994a) and Alam M.S. Alam (unpublished data). Therefore, preference of diet does not come in first order to striped hyena in GNPS ecosystem, but availability plays crucial deciding factor of feeding behaviour. Therefore, the available food may heavily depend on first, food preference of predator who hunt prey and second, abundance of prey species available to the predators for predation.

Striped hyena was observed in GNPS to eat on domestic refuse like bread, peas, sweets etc. Content like plastic material found in scats is an unknown behaviour hyena. Striped hyena was very rarely reported to damage the fruits and vegetables in farmland near by the GNPS (data from questionnaire survey). Also occurrence of cultivated fruits found in striped hyena scats and food remains at den sites was negligible. Moreover, in GNPS has high availability of farmlands, but only few records are there for the damaging brinjal (*Solenum melongena*) and chiku (*Manikara zapota*) farm near the protected area. We estimated rough quantity damage in these fruit vegetable grown at the edge of forest by hyena in these farms around 0.09% of total production.

The diet of the striped hyena is still a matter of some debate. However, it has been reported to consume a wide variety of vertebrates, invertebrates, vegetables, fruits, and human originated organic wastes (Harrison, 1968; Ilani, 1975; Kruuk, 1976; Macdonald, 1978; Leakey et al., 1999; Wagner, 2006). It is known to scavenge off lion, *Panthera leo* (Kruuk, 1976; Wagner, 2006; Alam et al., 2009) and spotted hyena kills (Kruuk, 1976; Wagner, 2006) and leopard kills (*personal observation* in GNPS) as well as discarded livestock carcasses (Leakey et al., 1999; Wagner, 2006; Alam et al., 2009). In many areas, striped hyenas have also been described as raiding human graves and carrying away bones (Rosevear, 1974; Horwitz and Smith, 1988; Leakey et al., 1999) that not reported from GNPS. Fruit and vegetable crop raiding is considered a serious problem in Israel (Kruuk, 1976), in Kuchch (*Personal communication* Y.V. Jhala).

Seasonal variation in diet is governed by seasonal variation in availability of recourse. In case of scavengers seasonal variation in diet could be due to the seasonal availability, preference or possibility. The possibility could be due to seasonal habitat change or breeding season of prey species. Buffalo was eaten more by striped hyena in winter season. Observation reveal said that there is more death of buffalo calves of maldharis living inside the sanctuary in winter than summer, thus more buffalo carcass bacame available in winter for scavengers. *Bor* (*Zizyphus spp.*) and *Timbru* (*Diospyros melanoxylon*) (Fig. 4.16) were found to be the most common fruits eaten by striped hyena in GNPS, resulting in seasonal variation in winter and summer diet. Both the fruits were eaten in proportion to their availability by striped hyena in their respective fruiting seasons, *Bor* in winter and *Timbru* in summer. Minimum number of scats to be analysed to detect

all possible mammalian prey species of striped hyena was found to be 40 scats which is more than lion and less than leopard (Lion 30 scats and leopard 70 scats, Mukherjee et al., 1994a).

Striped hyenas have been reported chasing hares, porcupines, bat-eared foxes, domestic cats, cheetah cubs, dikdik, reedbuck, and young gazelles (Kruuk, 1976; Skinner and Ilani, 1979). Further, there is strong evidence that small livestock (goats and sheep) and dogs are often killed by striped hyenas (Rosevear, 1974; Leakey et al., 1999; Wagner, 2006). In GNPS the striped hyena diet consist small mammals in good quantity with hare (*Lepus nigricollis*) in high frequency. And observation on food remains near den suggested that striped hyenas chase and catch small mammals and birds like peafowl (*Pavo cristatus*). There was no evidence found regarding small livestock killed by striped hyena in GNPS. However, radio telemetry study on hyena need to be conduct to monitor the food habit in respect to movement pattern and dependence on natural predators.

CHAPTER-5

HABITAT USE

5.1 Introduction

The habitat of an organism is the place where it lives, and may also refer to place occupied by entire community, that includes other organism as well as abiotic community (Odum, 1996). According to Caughley and Sinclair (1994), habitat is a resource (food, shelter) and environmental conditions (abiotic variables such as temperature and biotic variables such as competitors and predators) that determine the presence, survival, and reproduction of a population. And a resource is defined as something that an animal needs. The most obvious example of resource is food, and to that may be shelter, water, breeding sites, and a particular range of temperature. As the availability of resources rises, the fecundity (productivity) and probability of survival of an individual improved. Some component of the environment are resource at one level but become harmful where they are in superabundance, at which level they are not longer resource but problematic. A habitat comprises all those physical attributes of the environment that makes an area habitable for a species.

The monitoring of vegetation forms an essential component of the management of wildlife areas, since changes in vegetation influence the distribution and abundance of animal species. According to Dinerstein (1980), such studies have

been useful particularly in understanding the dynamics of animal population distribution, abundance and habitat use.

The selection of appropriate habitat by a species is the choice of setting that favour successful reproduction and survival (Robinson and Bolen, 1989), thus it is important to collect information on habitat selection of a target species for their long term conservation. As one cannot judge the adequacy of habitat only by human standards, because an environment that is apparently suitable in the eye of humans infract may be deficient in the perception of animal.

To maintain and improve habitat of a species we need a criteria important to the species that occupying them. Habitat selection may involve imprinting, a form of associate learning characterized by a rapid establishment of a perceptual preference for an object, some time it is partly a physiological process, and some time involves a hierarchical approach. Habitat selection is not rigid. Most species exhibit some plasticity; otherwise these animals would not colonize new habitats. The difference of habitat may result in plant species association with structural gradient and form their influence on composition, microclimate, and chemistry of the front floor that affect primary consumers or prey abundance (Smith, 1990).

Humans are increasingly entering wildlife habitats, that seriously causing wildlife-human conflict directly or indirectly. Many populations of large carnivores escaped extinction during the twentieth century owning to legal protection, habitat

restoration and changes in public attitudes. Successful management of wildlife has resulted in gradual recovery and return of carnivores to their original habitats that reduces the carnivore-human conflicts and damages to livestock in many areas worldwide.

The striped hyena is one of the least studied large carnivores. Very little is known about habitat selection and utilization by striped hyena in India as well as its other geographical range in the world. And whatever information is available are anecdotal and most of distribution this species is considered as data deficient. The striped hyena generally favours open or thorn bush areas in arid to semi-arid environments (Prater, 1971; Rosevear, 1974; Kruuk, 1976; Rieger, 1978; Wagner, 2006), where water is available within 10 km (Rieger, 1979a) and avoids open desert and dense thickets and forests (Rosevear, 1974; Rieger, 1979a; Heptner and Sludskii, 1980). From India no publish information is available on habitat use of striped hyena, thus it was important to collect data on habitat use pattern of striped hyena in forest ecosystem like Gir National Park and Sanctuary (GNPS) for their conservation and management. In chapter 3, we estimated striped hyena density by photographic capture-recapture techniques, in different zones of GNPS, and variation was observed in striped hyena density between different zones. To find out the factors for different striped hyena density in different zones of GNPS, we carried out vegetation sampling in those sampling zones at intensive level. This chapter deals with vegetation analysis in different sampling zones of GNPS and seasonal habitat use of striped hyena in GNPS.

5.2 Habitat characteristic of GNPS

Fifteen vegetation associations (Sharma et. al. 1999) and twelve habitat types were identified in GNPS (Khan et. al., 1990; Sharma and Jonsingh, 1996), further these habitat categories were clubbed into three broad habitat types (Qureshi and Shah, 2004), namely Moist Mixed vegetation, Thorn Forest, and Hill Forest, which were further divided into eight types. Apart from natural vegetation the water bodies (reservoir, rivers, ponds, and lakes), agriculture fields, orchards within GNPS was also considered.

a) Moist Mixed Vegetation

Moist Mixed Forest: The dominant species in western part was characterised by *Tectona grandis* which was replaced by *Anogiessus spp.* and *Acacia spp.* in eastern part of GNPS. The associated species with dominated were *Acacia spp,. Wrightia tictoria., Syzygium spp. Mitrragyna parviflora, Bauhinia racimosa, Diospyro melanoxylon,* and *Emblica officianalis.* The under storey comprises of *Acacia spp., Zizyphus spp., Grewia tiliaefolia, Helecteris isora, Carissa carandas, Manilkara hexandra,* and *Ixora arborea.*

Mixed Forest: The dominated species in west characterised by *Tectona grandis* which was replaced by *Anogiessus spp.* and *Acacia spp.* in eastern part and to large extent in central part of GNPS. The associated species with dominated were *Diospyro melanoxylon, Garuga pinnata, Gmelina arborea,* and *Mallotus phillipensis.* The under storey comprises of *Zizyphus spp., Acacia spp,. Wrightia*

tictoria., Grewia tiliaefolia, Helecteris isora, Carissa carandas, Manilkara hexandra, and *Caparis sepiaria.*

b) Thorn Forest

***Tectona* in west (replaced by *Anogeissus spp.* in the east) – *Acacia – Zizyphus*:** The co-associates were *Acacia spp., T. grandis* (replaced by *Anogeissus spp.* in east and to large extent in central part), *Zizyphus spp.*, and *Terminalia spp.*, and *the* under storey with *C.caranda, C. sepiara,* and *Zizyphus spp.*

***Acacia spp.-Zizyphus spp.*:** Thorn forest association *Acacia spp., Zizyphus spp.* with co-associates like *C. sepiaria* and *C. carandas.*

Scrubland: This associationis characterised by patchy and stunted growth of scrub species like *A. catechu, A. leucophloea, Zizyphus numularia* with co associates such as stunted *Zizyphus spp., C. sepiara* and, *Balanites aegiptica.*

Savanna: Scattered growth of trees like, *Acacia spp., Zizyphus spp., T. crenulata, B. racemosa, T. grandis, Anogeissus spp. Boswellia serrata,* and *Balanites aegyptica.* The grasses like *Apluda mutica, Heteropogon contotus,Themeda quadrivalis* and *Sehima nervosum* formed the ground layer.

c) Hill Forest

***Acacia-Anogeissus (Tectona* replaces *Anogeissus* in western part):** The co-associate species are *Acacia spp., Anogeissus latifolia, Terminalia spp. W. tinctoria, G. tiliaefolia, Boswellia serrata, Falcortia indica, B. racemosa,* and *Zizyphus spp.*

***Acacia-Lannea-Boswellia*:** The association is characterised by *Acacia spp., Lannea coromendelica, B. serrata, T. grandis, T. crenulata, W. tinctoria, Soyamida febrifuga* and *Sterculeia urens.*

5.3 Methodology

5.3.1 Vegetation Analysis

A useful study is that where vegetation data are collected and analyzed with the aims of providing information of relevance to some ecological problems, often to do with conservation and management. The forest resources are under great pressure owing to the increased demands from human and animal populations resulting in degradation of forest ecosystem. This has led to poor productivity and regenerative capacity. Hence, monitoring of vegetation is of great importance with relation to wildlife population. To fulfil the requirement of this study, we conducted intensive vegetation sampling in GNPS relation and affect of vegetation on striped hyena distribution.

The study area was divided into four zones on the basis of vegetation composition and management unit namely west zone, east zone, Central zone and NP zone

(national park zone) as divided for the camera trap survey in this research (chapter-3). Three transects of 3 km each were plotted in each zone for the vegetation sampling. In this way total 12 transects were plotted with total length of 36 km.

Sampling plot method was used for vegetation sampling. A sampling plot of 10 m radius circular plot was established at every 100 m interval with 31 plots at each transect, 93 plots in each zone and 372 sampling plots from the all sampled zones. The vegetation was classified into two groups >5 m as tree and <5 m as shrub. Different tree species and their individuals were recorded for the estimation of density, species diversity and species richness. Shrub layer was quantified in 5 m radius concentric circular plot within the existing 10 m radius sampling plot. Different shrub species and their numbers were recorded for the estimation of density, diversity and species richness.

The ground cover was estimated by point intercept method (Canfield, 1941). One meter long stick was marked at an interval of 5 cm. The stick was randomly laid in four directions and any intercepting material touching the mark was recorded. At any sampling plot, ground cover was calculated by taking the averages of all the frequencies. Tree cover was measured by using gridded mirror of 10 x 10 inches dimension, divided into 25 equal grids. The mirror was placed horizontally at 1.25 m above the ground touching the body of the observer. Tree cover was measured at 5 m distance from the sampling point in four different directions.

Grids covered with more than 50% foliage were counted and expressed in terms of percentage. Average of four recordings was taken for tree cover in each sampling plot. Data pertaining to habitat disturbance such as lopping of trees, fallen trees cattle dung and presence of fire were also recorded in the 10 m radius circular plot.

5.3.2 Habitat Use

Data on habitat use by striped hyena in GNPS was collected by direct and indirect method from April 2006 to July 2009. Habitat use of striped hyena was examined by determining proportion of location on the basis of direct and indirect evidences (foot print, resting sites, dens and scats) of striped hyena from all over the GNPS. The frequency of encountering striped hyena evidence direct or indirect in different vegetation types used as an indicator of habitat utilization. Whenever we encounter with striped hyena evidence, data on habitat type, latitude and longitude of that location and elevation using a GPS receiver (Garmin etrix), date and time, estimated distance to nearest water point and nearest Ness (human settlement) were collected. Data on vegetation characteristics were collected as discussed above in vegetation analysis.

Data on habitat use of lion (*Panthera leo persica*) and leopard (*Panthera pardus*) were also collected and recorded same as described for striped hyena, to find out the variation in habitat use between these three big carnivores of GNPS.

5.4 Data analysis

Density of trees and shrubs and of individual species was calculated for each sampling plot using the following formula:

Density = Number of Individuals / Area

Density values for each layer as well as individual species for each plot were added together to calculate mean densities and standard error for different sites. Species diversity, richness and evenness was calculated for trees and shrubs. Shannon-Weiner Diversity Index (H') was used for diversity, Margalef's Index (RI) for richness and Simpson's Diversity (D) was used for calculating evenness following Magurran (1988).

Shannon-Weiner Index: $H' = \Sigma\, p_i \ln p_i$.

Margalef's Diversity Index: $RI = (S-1) / \ln N$

Simpson's index: $D = \Sigma\, p_i^2$

Where p_i is the proportion of it species in sample, S is the number of species recorded and N = the total number of individuals summed over all the S species.

Groundcover was estimated by converting the value of each component into percentage (number of grid having a component $X \times 100$/total number of grid) and average value was taken from the number of sampling at each site.

Data was recorded as frequencies of encountering evidences in each habitat type and percentage frequency of each habitat was obtained as:

$$\%\text{age } f \text{ of } n \text{ habitat} = f \text{ of } n \text{ habitat} \times 100/\text{total } f \text{ number of all habitat types}$$

Where f is frequency and n is a specific habitat type.

Seasonal habitat use was calculated same as above of winter and summer, and chi square test was performed to observe seasonal variation in habitat use by striped hyena. Variation in habitat use by lion, leopard, and hyena in GNPS was also observed by calculating chi square test.

Habitat availability and utilization by striped hyena in GNPS was assessed (Neu et al. 1974). For the available habitat we followed the Qureshi and Shah (2004), where proportion of each habitat type was transformed in actual habitat area (km^2) from 1412.13 km^2 of GNPS. The data was analysed using the DOS-based statistical package PREFER (Prasad and Gupta, 1992). We hypothesized that striped hyena uses each habitat in proportion to its availability in GNPS. If a habitat type was used more than expected from its availability then it was preferred and vice-versa. If the expected proportional use is lower than both the Bonferroni confidence intervals lower as well as upper, the habitat is utilized more than expected by chance. If the expected proportional use lies beyond the

upper as well as lower confidence interval, than habitat is utilized less than expected, and if the expected proportional use is greater than the lower confidence limit but smaller than the upper confidence limit then animals utilize the habitat in proportion to its availability.

To understand the habitat use by striped hyena, data were subjected to Principal Component Analysis (PCA). All the quantitative data were transformed using Log and Arcsine transformation and were standardized following Zar (1984). Striped hyena density (result of chapter-3) was correlated with the habitat of different zones of GNPS.

5.5 Results

Total 210 random direct and indirect evidences of striped hyenas, 188 of lions, and 113 of leopards were recorded from all over the GNPS. Striped hyena was found around all the habitat type with preference of Mixed forest (40.46 ± 5.97 SE) and others as Moist mixed forest (8.09 ± 1.13 SE), *Tectona-Acacia-Zizyphus* (30.64 ± 4.5 SE), *Acacia-Tectona/Anogeissus* (1.16 ± 0.06 SE), *Acacia-Lannea-Boswellia* (8.67 ± 1.22 SE), *Acacia-Zizyphus* ((8.67 ± 1.22 SE), Scrubland (1.73 ± 0.17 SE), and Open area (0.58 ± 00 SE) (Fig. 5.1). A comparison between available and used habitat is shown in Fig. 5.2.

According to result of chi square test, we found that there is no difference in the habitat use of striped hyena between summer and winter in GNPS (Fig. 5.3).

Table 5.1 representing the frequencies of winter and summer habitat types and their respective chi square values.

Analysis of lion and leopard habitat use with special reference to compare with striped hyena habitat use in GNPS suggest that there is significant difference between two habitats that is Mixed forest and *Acacia-Lannea-Boswellia*, but in other case no difference was observed (Fig. 5.4). Percentage frequencies of lion, leopard, and hyena with chi sq values are given in Table 5.2.

The results of statistical program PREFER showed that Mixed forest is most preferred habitat type by striped hyena in GNPS. Habitat types like Moist mixed forest, *Tectona-Acacia-Zizyphus*, *Acacia-Lannea-Boswellia*, Thorn forst, Scrub lands and open area were utilized in proportion to its availability, while Acacia-Tectona/Anogeissus, savana and wetlands were avoided. Result of program PREFER summarized in detail with Bonferroni Confidence Intervals in table 5.3. Percentage contribution of different habitat type of GNPS is showed in Fig. 5.5.

Tree density was found as negative and grass was found as positive correlation with the hyena density. The correlation of striped hyena population and habitat variables with their respective significant level is presented in table 5.4. Tree density, diversity, richness and evenness in different habitat types were represented in table 5.5, 5.6, 5.7 and 5.8, respectively.

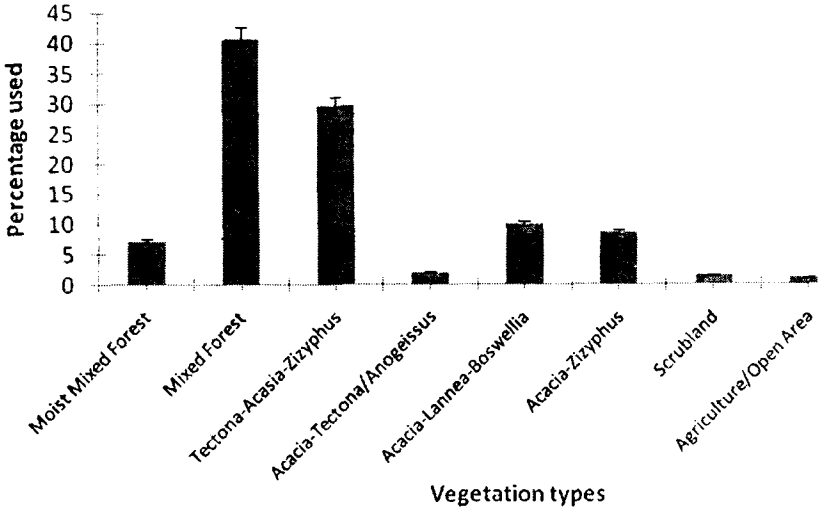

Fig. 5.1: Percentage frequency of habitat use by striped hyena with 95% confidence limit in GNPS.

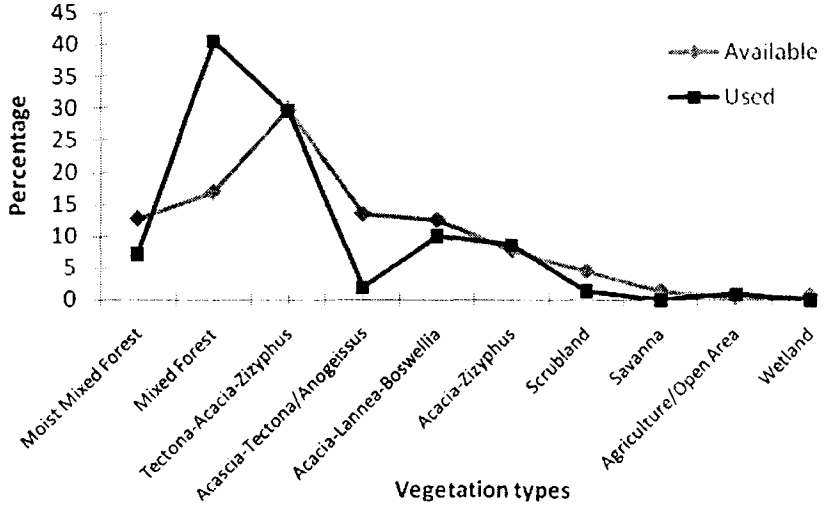

Fig. 5.2: The habitat types available and used by striped hyena in GNPS.

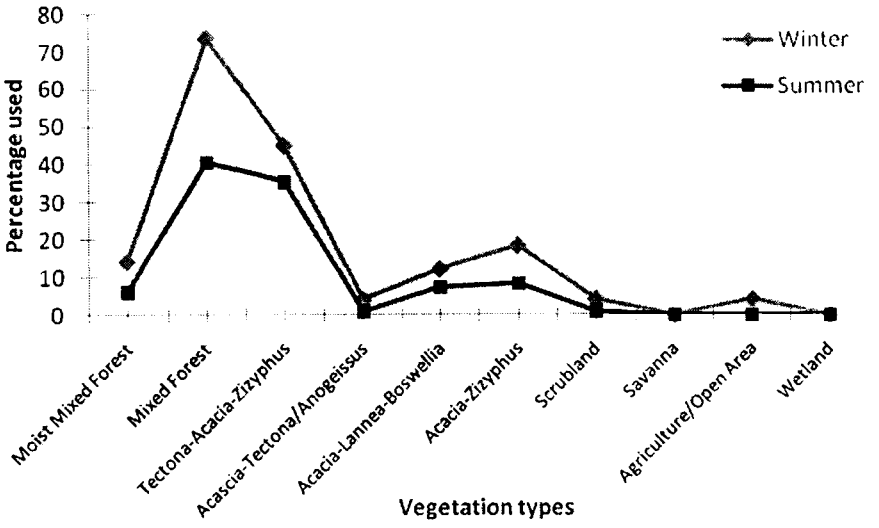

Fig. 5.3: Habitat use variation between summer and winter of striped hyena in GNPS.

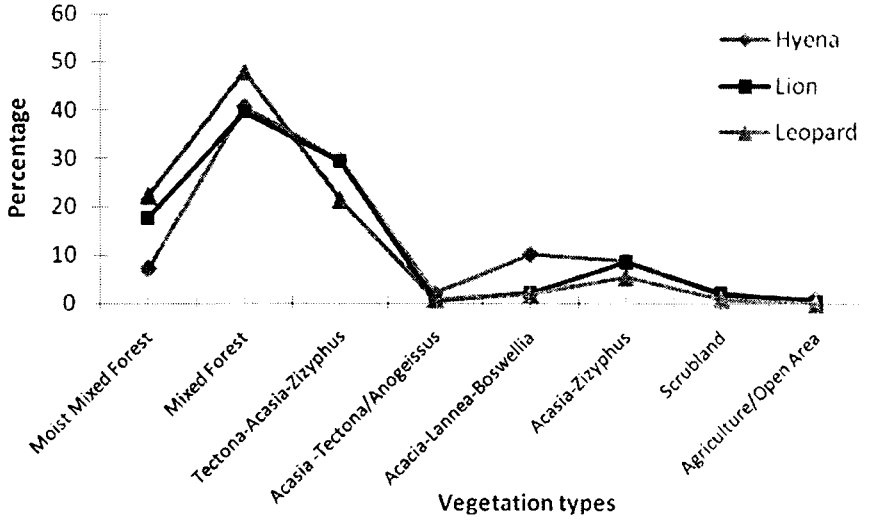

Fig. 5.4: Variation of habitat use pattern between lion, leopard, and hyena in GNPS.

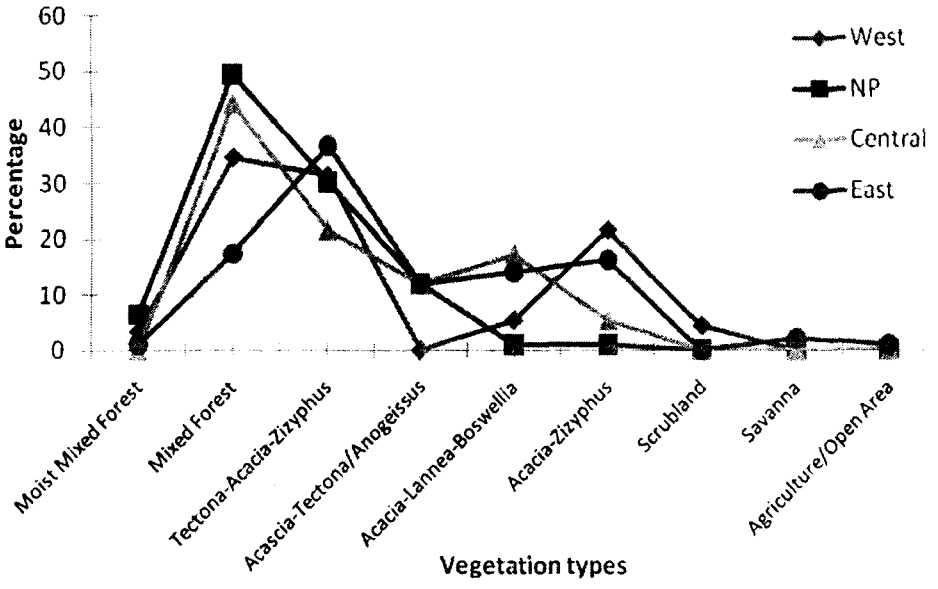

Fig. 5.5: Percentage contribution of different habitat types found in camera trap sampled zones in GNPS.

Table 5.1: Percentage frequencies of summer and winter habitat of striped hyena and values of chi-sq test.

Vegetation type	**Summer**	**Winter**	**Chi-sq**
Moist Mixed Forest	12.24	6.25	1.41
Mixed Forest	42.86	40.63	0.04
Acacia-Tectona/Anogeissus	26.53	35.42	0.79
Acacia-Lannea-Boswellia	0.00	1.04	0.51
Tectona-Acacia-Zizyphus	0.00	7.29	3.57
Thorn Forest	12.24	8.33	0.51
Scrubland	4.08	1.40	1.45
Open area	2.04	0.00	1.96

Table 5.2: Percentage frequencies of lion, leopard, and hyena habitat use of GNPS and chi-sq values.

Vegetation type	**Lion**	**Leopard**	**Hyena**	**Chi-sq**
Moist Mixed Forest	16.91	24.62	8.09	8.85
Mixed Forest	38.24	47.69	40.46	0.95
Acacia-Tectona/Anogeissus	32.35	18.46	30.64	3.44
Acacia-Lannea-Boswellia	0.00	0.00	1.16	1.39
Tectona-Acacia-Zizyphus	0.74	0.00	8.67	6.93
Thorn Forest	8.82	7.69	8.67	0.20
Scrubland	2.21	1.54	1.73	0.10
Open area	0.71	0.00	0.58	0.47

Table 5.3: Results of habitat preference or avoidance (using PREFER Program) by the striped hyena in Gir National Park and Sanctuary, Gujarat, India. Values in parenthesis represent the Bonferroni Confidence Intervals.

Habitat Type	**Total Area (Km^2)**	**Relative Area**	**Exp. Use**	**Expected Prop. Use (*Pi*)**	**Vale of Confidence Interval**
Moist Mixed Forest	180.19	0.128	22.073	0.128	($0.023 \leq Pi \leq 0.139$) **
Mixed Forest	239.36	0.169	29.321	0.169	($0.300 \leq Pi \leq 0.509$) ***
Tectona-Acacia-Zizyphus	419.54	0.297	51.392	0.297	($0.208 \leq Pi \leq 0.405$) **
Acacia/Tectona-Anogeissus	190.36	0.135	23.319	0.135	($0.000 \leq Pi \leq 0.034$) *
Acacia-Lannea-Boswellia	177.08	0.125	21.692	0.125	($0.027 \leq Pi \leq 0.147$) **
Thorn Forest	109.16	0.077	13.372	0.077	($0.027 \leq Pi \leq 0.147$) **
Scrubland	63.26	0.045	7.749	0.045	($0.000 \leq Pi \leq 0.045$) **
Savana	19.49	0.014	2.387	0.014	($0.000 \leq Pi \leq 0.000$) *
Open area	4.10	0.003	0.502	0.003	($0.000 \leq Pi \leq 0.022$) **
Wetland	9.74	0.007	1.193	0.007	($0.000 \leq Pi \leq 0.000$) *

* - Avoided
** - Utilized in proportion to its availability
*** - Utilized more than expected

Table 5.4: Correlation of hyena density with the vegetation characteristics of the GNPS with significant level.

S. No.	Variables	Correlation values	Significant level
1	Tree density	-0.172	0.001
2	Tree richness	-0.137	0.008
3	Tree diversity	-0.041	0.432
4	Tree evenness	0.028	0.585
5	Shrub density	-0.007	0.896
6	Shrub richness	-0.122	0.018
7	Shrub diversity	-0.072	0.164
8	Shrub evenness	-0.044	0.394
9	Grass cover	0.199	0.000
10	Litter	-0.073	0.160
11	Bare ground	-0.138	0.008
12	Rock	-0.135	0.009
13	Herb	0.035	0.505
14	Tree height	0.030	0.559
15	Canopy	-0.005	0.931
16	Elevation	-0.173	0.001

Table 5.5: Tree density/ha in different habitat types of GNPS.

Zone	**Moist Mixed Forest**	**Mixed Forest**	***Tectona-Acacia-Zizyphus***	***Acacia-Tectona/ Anogeissus***	***Acacia-Lannea-Boswellia***	***Acacia-Zizyphus***	**Scrubland**
West	424.63	584.20	439.49	0.00	585.99	303.39	167.20
NP	605.10	560.79	418.56	390.85	318.47.13	159.24	0.00
Central	0.00	484.53	425.16	366.24	425.39	178.34	0.00
East	31.85	369.43	382.17	353.21	411.56	284.41	0.00

Table 5.6: Tree diversity in different habitat type of GNPS.

Zone	**Moist Mixed Forest**	**Mixed Forest**	***Tectona-Acacia-Zizyphus***	***Acacia-Tectona/ Anogeissus***	***Acacia-Lannea-Boswellia***	***Acacia-Zizyphus***	**Scrubland**
West	0.62	0.70	0.55	0.00	0.71	0.45	0.27
NP	0.81	0.68	0.48	0.61	0.47	0.22	0.00
Central	0.00	0.71	0.56	0.55	0.63	0.36	0.00
East	0.00	0.70	0.64	0.56	0.61	0.40	0.00

Table 5.7: Tree richness in different habitat type of GNPS.

Zone	**Moist Mixed Forest**	**Mixed Forest**	***Tectona-Acacia-Zizyphus***	***Acacia-Tectona/ Anogeissus***	***Acacia-Lannea-Boswellia***	***Acacia-Zizyphus***	Scrubland
West	1.94	2.11	1.59	0.00	2.32	1.71	1.32
NP	2.61	2.15	1.36	1.64	1.30	0.62	0.00
Central	0.00	2.17	1.84	2.012	2.46	1.56	0.00
East	0.00	2.07	1.87	1.60	1.71	1.33	0.00

Table 5.8: Tree evenness in different habitat type of GNPS.

Zone	**Moist Mixed Forest**	**Mixed Forest**	***Tectona-Acacia-Zizyphus***	***Acacia-Tectona/ Anogeissus***	***Acacia-Lannea-Boswellia***	***Acacia-Zizyphus***	**Scrubland**
West	0.74	0.86	0.80	0.00	0.84	0.76	0.62
NP	0.91	0.84	0.74	0.89	0.77	0.64	0.00
Central	0.00	0.88	0.78	0.76	0.74	0.39	0.00
East	0.00	0.91	0.88	0.87	0.88	0.69	0.00

Table 5.9: Shrub density/ha in different habitat types of GNPS.

Zone	Moist Mixed Forest	Mixed Forest	*Tectona-Acacia-Zizyphus*	*Acacia-Tectona/ Anogeissus*	*Acacia-Lannea-Boswellia*	*Acacia-Zizyphus*	Scrubland
West	254.78	436.06	229.30	0.00	152.87	127.39	63.69
NP	618.74	702.05	400.36	1366.53	1019.11	0.00	0.00
Central	0.00	988.04	677.17	694.85	429.94	127.39	0.00
East	0.00	660.83	337.20	343.95	382.17	284.75	0.00

Table 5.10: Shrub diversity in different habitat type of GNPS.

Zone	Moist Mixed Forest	Mixed Forest	*Tectona-Acacia-Zizyphus*	*Acacia-Tectona/ Anogeissus*	*Acacia-Lannea-Boswellia*	*Acacia-Zizyphus*	Scrubland
West	0.14	0.05	0.04	0.00	0.06	0.02	0.00
NP	0.19	0.12	0.06	0.14	0.32	0.00	0.00
Central	0.00	0.18	0.13	0.08	0.20	0.00	0.00
East	0.00	0.09	0.05	0.01	0.06	0.02	0.00

Table 5.11: Shrub richness in different habitat type of GNPS.

Zone	Moist Mixed Forest	Mixed Forest	*Tectona-Acacia-Zizyphus*	*Acacia-Tectona/ Anogeissus*	*Acacia-Lannea-Boswellia*	*Acacia-Zizyphus*	Scrubland
West	0.41	0.35	0.25	0.00	0.47	0.04	0.00
NP	0.49	0.34	0.25	0.37	0.96	0.00	0.00
Central	0.00	0.65	0.49	0.53	0.79	0.30	0.00
East	0.00	0.28	0.17	0.17	0.27	0.24	0.00

Table 5.12: Shrub evenness in different habitat type of GNPS.

Zone	Moist Mixed Forest	Mixed Forest	*Tectona-Acacia-Zizyphus*	*Acacia-Tectona/ Anogeissus*	*Acacia-Lannea-Boswellia*	*Acacia-Zizyphus*	Scrubland
West	0.28	0.10	0.07	0.00	0.18	0.05	0.00
NP	0.41	0.28	0.16	0.28	0.61	0.00	0.00
Central	0.00	0.38	0.25	0.19	0.41	0.00	0.00
East	0.00	0.20	0.13	0.03	0.15	0.05	0.00

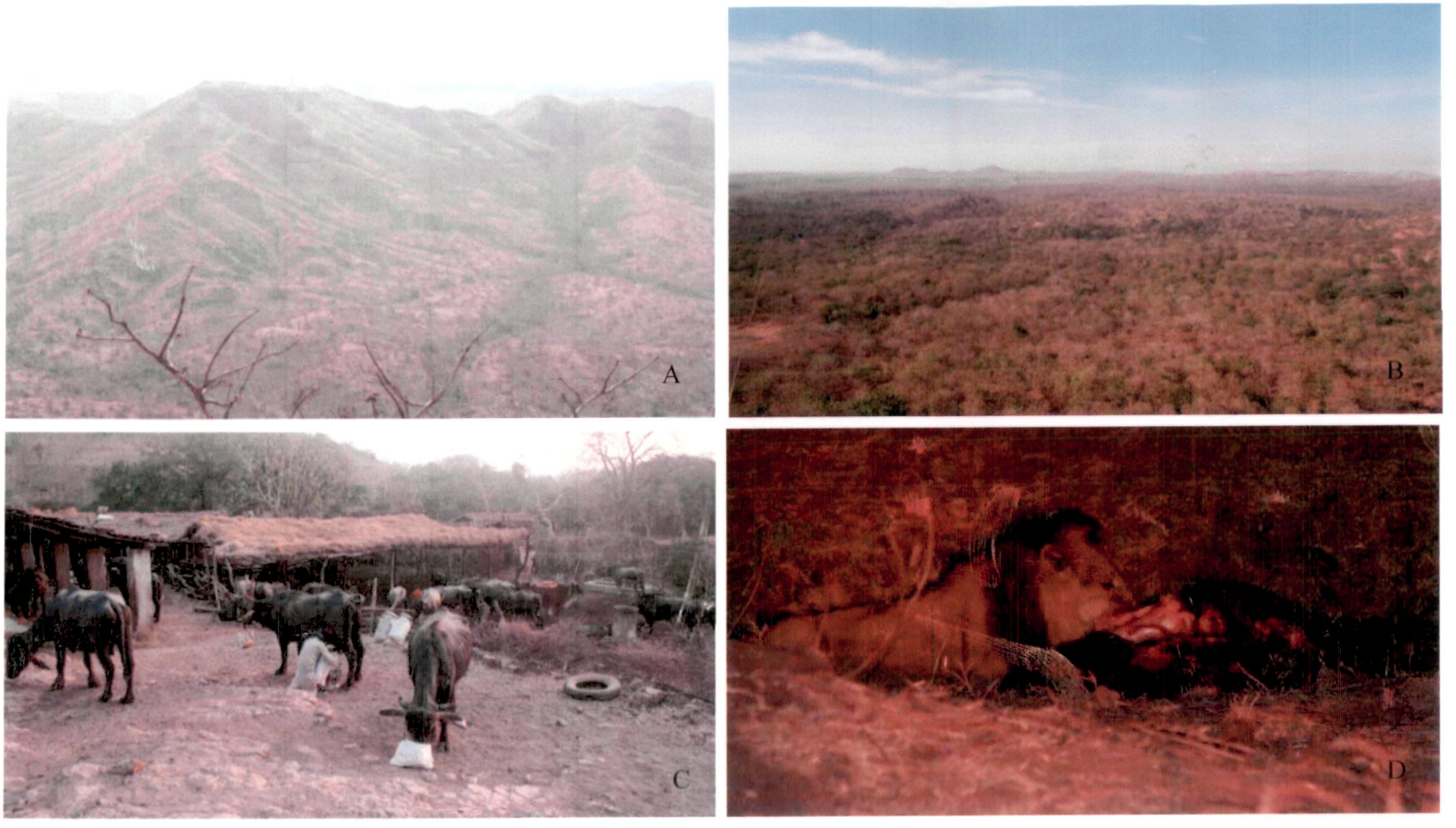

Fig. 5.6: A typical landscape and vegetation cover in eastern (A), and western (B) GNPS. A typical Maldhari Ness in eastern part (C), lion killed a buffalo near Ness (D) in GNPS.

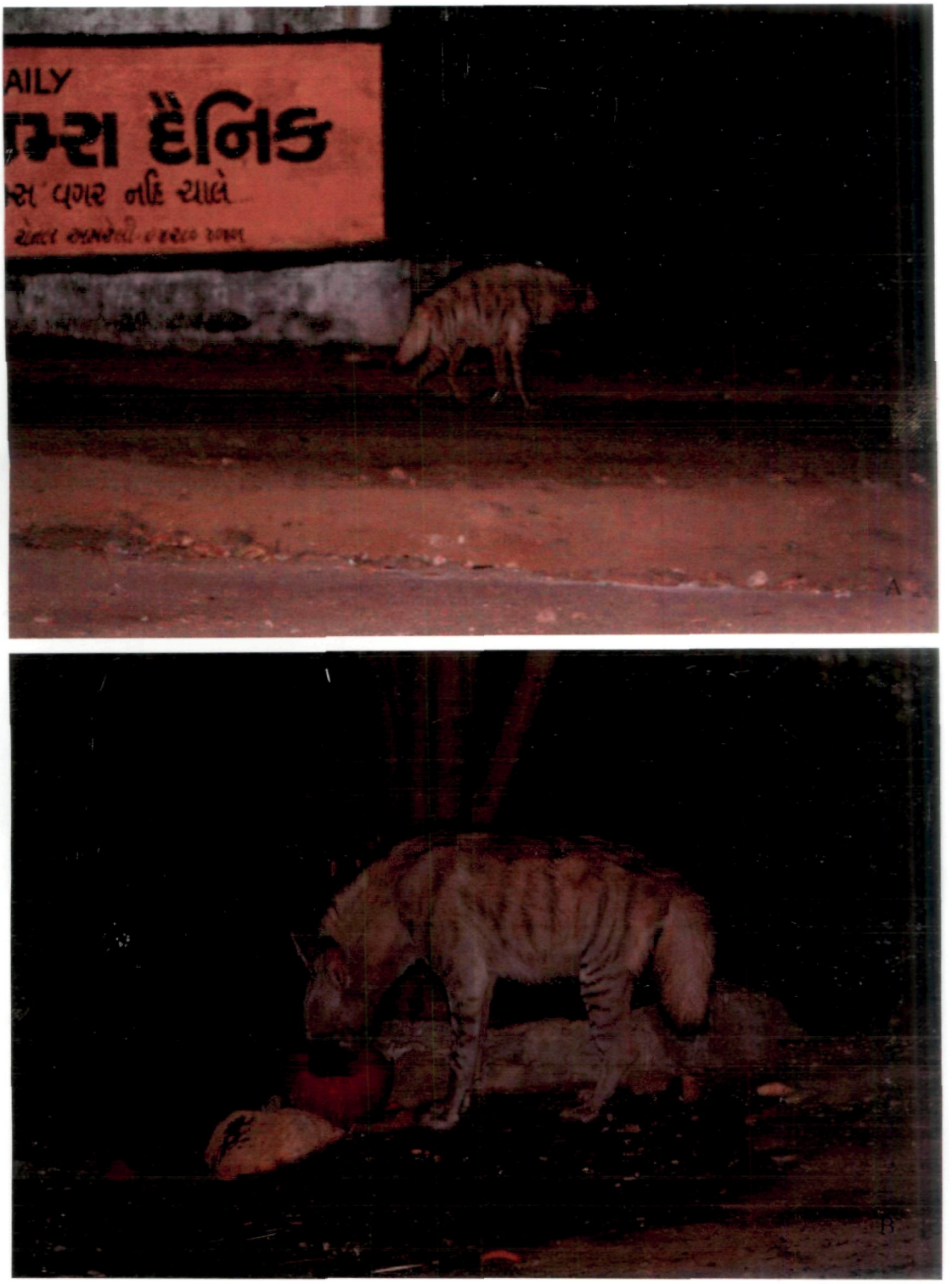

Fig. 5.7: A striped hyena walking on road in front of cemented wall with an advertisement of a Gujarati news paper near Tulshishyam temple (A), and a hyena drinking water in an earthen pot near the Ness (B) in eastern part of GNPS.

5.6 Discussion

Food and shelter are the two very important requirements for any animal to survive. The habitat of an organism is the place where it lives, that provides all the resources and environmental conditions in which a species survives and reproduces successfully. The variation in habitat determined by the different composition of plant species that gives the structure to a habitat and acts as producers for the primary consumers in the ecosystem, from where a cycle of complex food chain starts. All the species are dependent on each other directly or indirectly. The striped hyena a carnivore and specialised scavenger is not fit for hunting morphologically, but feed on prey killed by other animals, a resource provided by habitat by other species or by community living in the same habitat.

In GNPS striped hyena uses all the habitat types with some preference of mixed forest and thorn forest, followed by hill forest where they perform denning and rear young ones. There was no difference in habitat use was found in striped hyena seasonally (winter and summer), suggesting equal use of habitat in both the season, but movement pattern could vary between season due to change in availability, distribution, and requirement of water in the habitat. Thus radio telemetry study is necessary to monitor the movement pattern with special reference to habitat.

In two habitat types significant difference were found between lion, leopard, and striped hyena. Moist mixed forest that is avoided by the hyena and hill forest that

is more used by hyena compare to lion and leopard. In GNPS all the dens and resting sites of striped hyena were located in hilly areas only, suggesting preference hilly habitat to avoiding disturbance by natural predators (lion and leopard because they least prefer hilly habitat), and for success in survival and in reproduction.

Mean habitat variables, tree density, tree diversity, tree richness, tree evenness (table 5.5, 5.6, 5.7, 5.8, respectively) and shrub density, shrub diversity, shrub richness, shrub evenness (table 5.9, 5.10, 5.11, 5.12, respectively) were found different in habitat types of different Zones of Gir. As in all four zones of GNPS distribution of different tree species with varying topographic and climatic conditions.

When we correlated the hyena density that varies in different zones of GNPS with habitat, tree density was found negative correlated while grass availability with the positive correlated. West Gir Zone has the lowest hyena density where tree density is more and grass was found in less abundance. In Gir East Zone hyena density was found highest where tree density was low and grass was in high abundance. Grass cover may provide a good hide in their denning and resting sites that also camouflage with the colour of the striped hyena in the winter and summer seasons.

Generally striped hyena favours open or thorn bush country in arid to semi-arid environments (Prater, 1971; Rosevear, 1974; Kruuk, 1976; Rieger, 1978; Leakey et al., 1999; Wagner, 2006). Gir east sanctuary is more open with thorn bushy vegetation, where we found highest hyena density, compare to west sanctuary which has dense vegetation cover.

While active, the striped hyena may cross more open areas, but they actively seek out relatively heavy vegetative cover or rocky depressions, particularly large caves, for resting (Rosevear, 1974; Kruuk, 1976; Rieger, 1979a; Leakey et al., 1999; Wagner, 2006). In GNPS Eastern part is more undulating with un-patterned ridges that provide good availability of refuge for the resting and denning, compare to western part. NP and Central Zones are also undulating compare to western Zone (Fig. 5.6). Also NP and Central Zones has good abundance of grass with undisturbed refuge for denning.

The other reason for having high density in eastern part of GNPS could be the more number of nesses, human settlements (Fig. 5.6) and livestock availability. Striped hyena may remain active in areas frequented by humans (Fig. 5.7), while avoiding them on a temporal scale (Rosevear, 1974; Kruuk, 1976; Wagner, 2006) (Fig. 5.7). The availability of safe refuge with human and livestock presence (alternative food from the carcass by natural causes and predators) may govern the population of hyena. Also the high density of natural predators of GNPS (Asiatic

lion from 2010 census and leopard by personal observation) in eastern part of Gir provides more availability of carcass for the natural scavengers like striped hyena.

CHAPTER-6

DENNING AND BEHAVIOR

6.1 Introduction

Striped hyena is generally found in open area, haunting rocks and low cover, and hiding by day in caves or its own burrows. The striped hyena is one of those carnivores, which has acquired distinctive habit of digging den. According to Prater (1971), striped hyena takes shelter in den, high grasses, under bushes or in cane fields. The den usually preferred is a cave in rocks or a hole dug in side of a hill or ravine and some time they enlarges a porcupine's burrow for own use. Den play an important role in the striped hyenas daily life as well as processes like breeding and rearing young ones etc. There is lack of data on habitat selection for denning and resting of striped hyenas in India as well as in its other geographical distribution ranges.

According to Pocock (1941), Ronnefeld (1969), Heptner and Sludskij (1980), in the wild condition litter size varies from one to four throughout the year, after a gestation period of 90-91 days. And in captivity it ranges from one to five (Rieger, 1979a). According to Rieger (1979a) pups are born blind, with white to grey fur with prominent black stripes on the body. Eyes first open after seven to eight days, and teeth erupt from day 21 onwards. Pups begin to eat meat at the age of 30 days. Weaning takes place in captivity after eight weeks (Heptner and Sludskij,

1980). In the wild pubs have been observed suckling until four to five months of age (Rieger, 1981), or up to 10-12 months (Kruuk, 1976).

The purpose of this study was to better understand striped hyena den, den site selection and characteristics to support effective, long-term conservation and management of striped hyenas in Gir National Park and Sanctuary (GNPS). The objectives were: 1) to determine striped hyena den site characteristics; 2) to investigate factors influencing den site selection at fine and course scales; and 3) to investigate the behavior and social organization of striped hyena in GNPS.

6.2 Methodology

Dens and resting sites were selected for the sampling and data pertaining to vegetation characteristics and den parameters were collected on well planed data sheet. Number of tree in ten meter with species name, habitat type, Number of shrub and ground cover were recorded from five meter plot within ten meter plot. Den opening parameter and slop of terrain and direction of opening or hill slop were also recorded. GPS location and elevation was recorded using GPS receiver (Garmin etrix). All the active dens were sampled only in the absence of animals and rendezvous sites were sampled only after the animal changed the den. Approx distance to nearest water point, and temporary human settlement (Ness) and disturbance were also recorded.

All the measurements of den opening were taken using measuring tape and direction with compass. The ground cover was estimated by point intercept method (Canfield, 1941). One meter of stick with 20 graduations each at five centimeter of interval was placed on the ground and intercepting materials such as grass, rock (stone), bare ground and litter were recorded at each interval.

Density of trees and shrubs were calculated at each den and resting site using the following formula (represented as mean density/ha):

$$\text{Density} = \text{Number of Individuals} \times 10{,}000/\ \text{Area}$$

Groundcover was estimated by converting the value of each component into percentage (number of grid having a component $X \times 100$/total number of grid) and average value was taken from the number of sampling at each site.

Striped hyena is a nocturnal animal and activity starts from 1-2 hours before dusk and stops 1-2 hours after dawn near the dens. Active dens were searched during the status survey as discussed in chapter 'status and distribution' of this report. Active dens were monitored regularly at dawn and dusk from a hide from an appropriate distance, which varied from place to place depending on terrain (moderate hilly to steep slope) and vegetation, using binocular and spot scope avoiding disturbance to animals. During the monitoring of dens due care was taken to avoid detection through aural, visual or olfactory sense of the animals.

We kept ourselves in camouflaged cloths according to the surrounding habitat without using any fragrance or perfume and silence was maintained very strictly. Data were recorded on the behavior of all individual present near the den. Each individual was tried to be identifed with natural markings, body size, and coat colour. Wherever possible, behavioral activities were documented using a camera (Canon EOS 350D). Other than the den observations opportunistic observation were made, Data on activity, number of individuals (interaction with co-specifics), morphological condition, time, date, climate condition, place, habitat type, GPS location, elevation, nearest water point and nearest ness (temporary human settlement inside GNPS) were also recorded.

6.3 Results

6.3.1 Den Characteristic

A total 28 dens and 30 resting sites were searched from different parts of GNPS. All were found in hilly terrain and most of them in middle of the hill slope and some of them on top of the hill. Out of 28 dens 23 dens were sandy and only 5 were rocky, while out of 30 resting sites 24 were sandy and only 6 dens were rocky. Percentage of sandy and rocky den and resting site is presented in Fig. 6.1.

Most of the den found to have on north east (25%), and north (21.88%) aspect of hill slope. While maximum resting sites were on west (45.45%) followed by north (27.27%) aspect of hill slope (Fig. 6.3). Mean elevation above mean seas level (AMSL) in meter were recorded as for den 232m and for resting sites 237m

(throughout the GNPS hill forest habitat were preferred for the denning and resting), and mean hill slope preferred for denning and resting site was found to be about $\angle 50^0$. Around 46.13% dens were found to be approachable through front and 53.13% dens were through lateral side. Mean height, width, and circumference for den openings were 37, 49, and 133 centimeters respectively (Fig. 6.2). Tree and shrub densities were 514/ha and 356/ha for den respectively, and 486 /ha and 487/ha for resting sites, respectively (Fig. 6.4).

In terms of ground cover den sites were mostly covered with litter (31.5%) followed by grass (27.5%), and similar trend was found for the resting sites, litter (36.7%) followed by grass (22.95), (Fig.6.5). The canopy cover was estimated as for den sites around 19%, and for resting sites around14%.

6.3.2 Behavior

More than 13820 minutes of active observations were opted spreading over 72 dawns and dusks, from hide to gather data on striped hyena's behavior near den and activity of pups and their relation to adult individuals. Observations were made from dens near Khada, Jamuthala, Kasia, Mundachauk, Biliat, and Tulsishyam areas. At all the sites pups were found except Jamuthala and Mundachauk where only one mature striped hyena was reported. Apart from den sites opportunistic observations were also recorded. Observations made in this study was described and discussed in the following categories:

6.3.2.1 Den

The striped hyena uses three types of structures for the resting and pup rearing in GNPS. First type can be defined as resting place which is partially dug and open most of the times sandy and at few occasions along the rocky boulders. Second type is a small den with not more than a meter deep dug in sandy place, sometimes under live tree trunk and occasionally natural rocky cave (Fig. 6.7, 6.7) used for the resting in the day time. Third type is usually sandy dens (n=7) with multiple openings (2-3) only few time rocky (n=1), more deep (1- 4 m), with 1-2 small chambers, used for pup rearing for a long period of time, this type of den is regarded as rendezvous site.

6.3.2.2 Litter size and breeding season

The mean litter size was found 3 ± 0.24 SE, ranges from 2-4 pups. The newly born pups were observed in winter from January – March (n=9) and age was estimated from body size.

Khada female was located with two newly born pups on 28th February 2006 and on January 17th 2007, she was again located in the same area with four newly born with closed eyes in freshly constructed sandy den. She used three dens out of eight that were used previous year during den shifting. While Kasia female hyena was first located with three pups of around three to four months old on 23rd May 2006, and again with three pups next year of around one month old in February 2007 at the same area and in the same sandy den that was used previous year. She

used three out of three previously used dens. Tulsishyam female was located first in March 2008 with three pups around one and half month old and the Biliat den (the only communal den observed in GNPS) was located with six pups in two different age groups, three pups around four months old and three pups around two months old in May 2008 with two adult female.

6.3.2.3 Clan size

Striped hyena was found solitary at all the active times but clans (a group of hyena) was observed at den site. Mean number of individuals in clan was estimates with confidence interval as 3.74 ± 0.05 SE. The largest clan was of 8 individual and smallest of 3 individuals in GNPS. Table 6.1 list the number of individuals observed at different den sites in GNPS.

6.3.2.4 Interaction of pups with mother and other individuals

Mother usually stayed with pups in the same den, seldom moves out of den but remains in close proximity when pups are very young (1-3 month), and mothers were observed resting at far place around 50m to 150m (n=5), in day time when pups became little old. At Khada in 2007 two pups of the previous litter of the same female now sub adults were found, helping the mother in rearing of new young ones, but did not found any hyena other than the mother was found in the Kasia den sites. Sub adults were found to stay near the den and protect the pups in the absence of mother, and bringing hidden food (pieces of carcass) to the pups. They were also involved in the den cleaning and den enlarging process.

Female used to return to the den in the evening about an hour before sunset, then pups emerged from the den with a little lament sound (sometimes pups also came out in the absence of adults quietly and play just near the den) and within 1-2 minutes females started to lactate. The mean duration of lactation with 95% confidence interval was 12.94 ± 1.09 SE minutes that vary from 5-25 minutes (n = 18). Females were found, lactating pups just outside the den the morning as well as in the evening time within 10-15 meter of radius. After lactation pups start playing outside the den and female after cleaning their body with tongue, also take a short nap outside the den within 15 meter, till darkness. Sometimes sub-adults also take rest near the den in the presence of mother. When sub-adults meet with the mother, they perform a greeting ceremony that lasts for few seconds, in which sub-adults bow down their both fore legs in front of mother and try to keep their head between the mothers fore legs for a short period of time (n=4).

6.3.2.5 Interaction between adult striped hyenas

Sighting of striped hyena is very rare in GNPS due to low density and nocturnal habit. Out of 11 observations at feeding site only three times two striped hyena were seen together while other than feeding sites during night monitoring of forest roads, animal was found solitary in all the sixteen sightings. Out of three observations of more than one individual striped hyena, in the two observations aggressive behavior was recorded between the individuals, of which one

aggression lasted for more than 15 minutes with biting each other and growling in aggression posture, tail upward side.

Identification of male and female striped hyena was found very difficult in the wild condition and also in captivity (Mr. Katara, Sakarbaug Zoo officer, *Personal comm.*), and did not found any morphological difference between them. In all the sighting and camera trap photograph of striped hyena males and females were not differentiated except in one photograph where a lactating female was identified.

6.3.2.6 Vocalization

The striped hyena was found very calm animal that rarely uttered any sound. Only five types of different vocalizations were recognized. First is from pups when they whine before suckling very softly, second again by pups when they perform play fights with each other some low-growl type (n=12), third by mother for pups (like cow call) produce to alarm of any danger (n=2), fourth when hyena meets with the another family member then whoop (*wo..wo..wooo..*) like sound (n=3) and fifth loud growl by adult at the time of aggression on another individual hyena, or other competitor like leopard (n=1and also from personal communication with forest staffs and Maldharis).

6.3.2.7 Storing of food

In GNPS, striped hyenas were observed to store food, usually at rendezvous sites where pups were kept for rearing for a long period of time. A large amount of

bones of chital, sambar, buffalo, skins of chital, buffalo, and cow, antlers, horns of buffalo, skull of chital, buffalo, cow, langur and hares, limbs of chital, sambar, buffalo, and cow, feathers of peafowl and other birds, and fresh flesh of chital, buffalo, and porcupine etc were observed near dens sometimes hidden inside the den and sometime just outside near the den. Occasionally (n=2) crows and white backed vultures were found attracted at den sites due to fresh meat pieces.

Table 6.1: Details of number of individuals observed at different den sites in GNPS.

Den site	**Adult**	**Sub-adult**	**Pup**	**Total**
Khada 2006	1	-	2	3
Khada 2007	1	2	4	7
Khada 2008	2	-	-	2
Khada 2009	2	-	4	6
Keramba 2010	2	-	-	2
Kasia 2006	1	-	3	4
Kasia 2007	1	-	3	4
Jumuthala 2006	1	-	-	1
Mundachuk 2007	1	1	-	2
Tulsishyam 2007	2	1	-	3
Tulshishyam 2008	3	1	3	7
Tulshishyam 2009	2	2	-	4
Biliat 2008	2	-	6	8
Biliat 2009	1	-	-	1
Jamvali 2008	1	-	-	1
Karangsa 2008	1	-	-	1
Banej 2008	1	-	2	3
Total	25	7	27	59

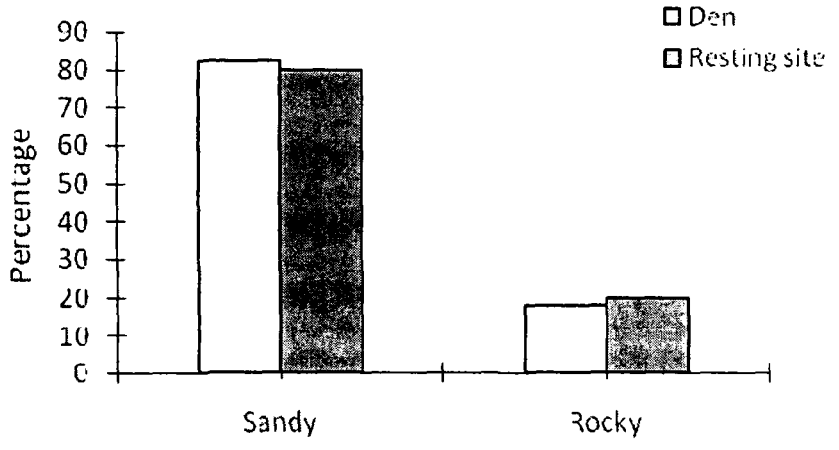

Fig. 6.1: Percentage of sandy and rocky den and resting sites found in GNPS.

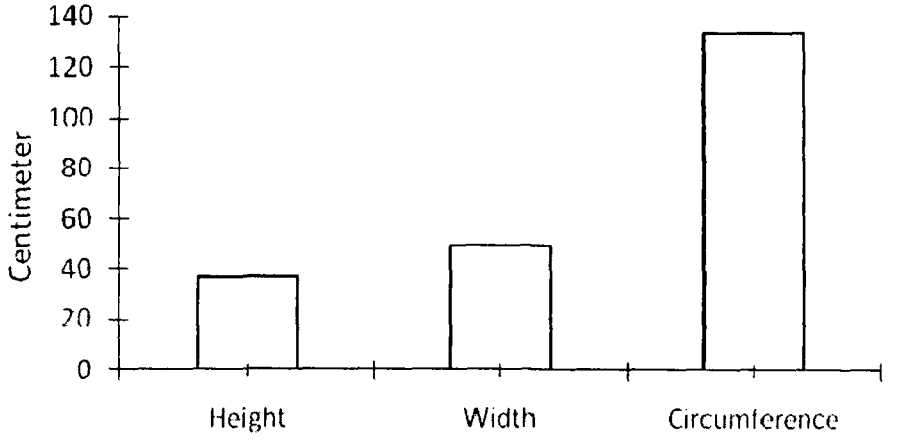

Fig. 6.2: Mean height, width, and circumference of striped hyena den in GNPS.

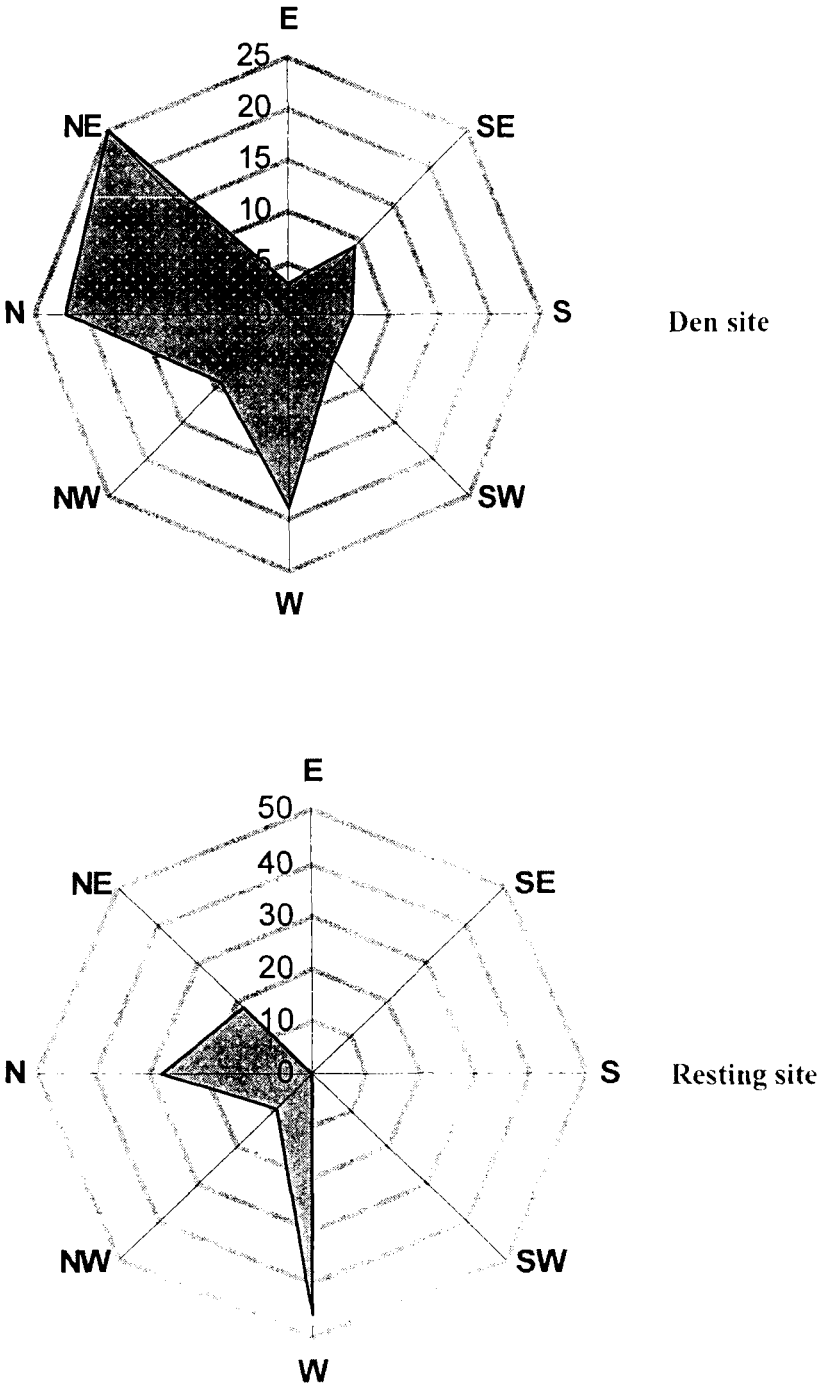

Fig. 6.3: Showing aspect of hill slope preferred for denning site and resting site by striped hyena in GNPS.

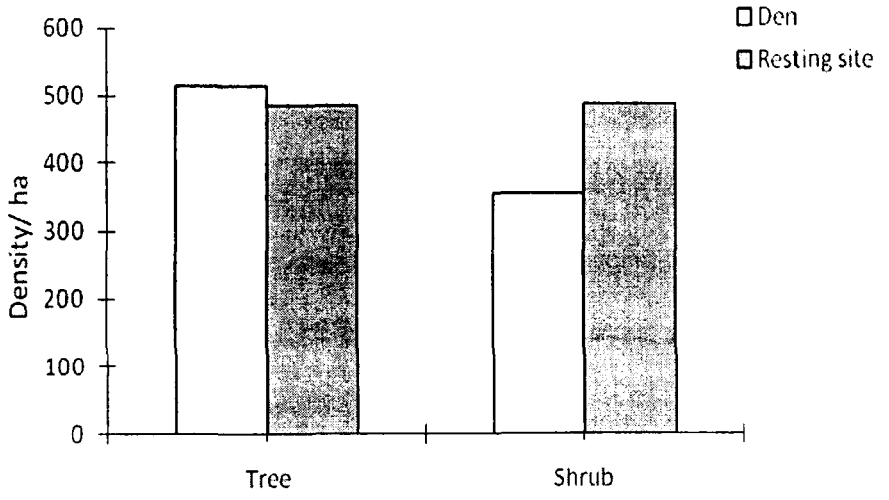

Fig. 6.4: Tree and shrub density at den and resting sites of striped hyena in GNPS.

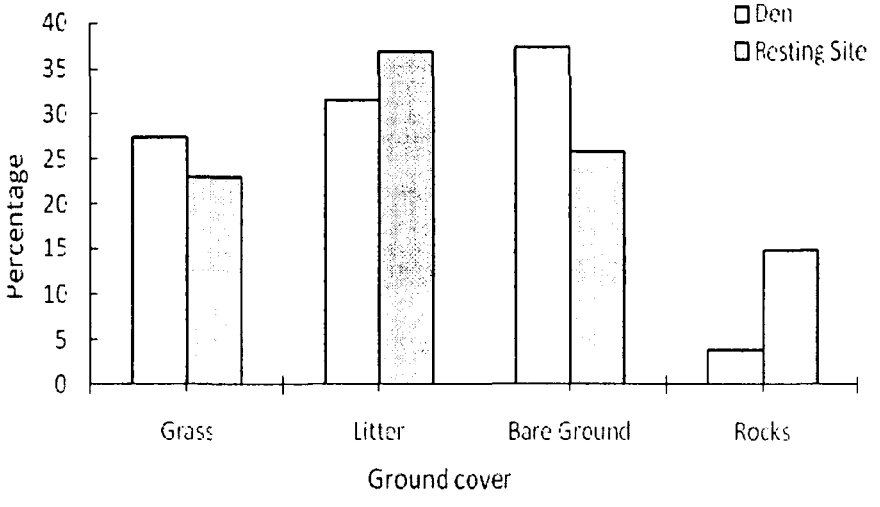

Fig. 6.5: Percentage ground cover calculated at den and resting sites of striped hyena in GNPS.

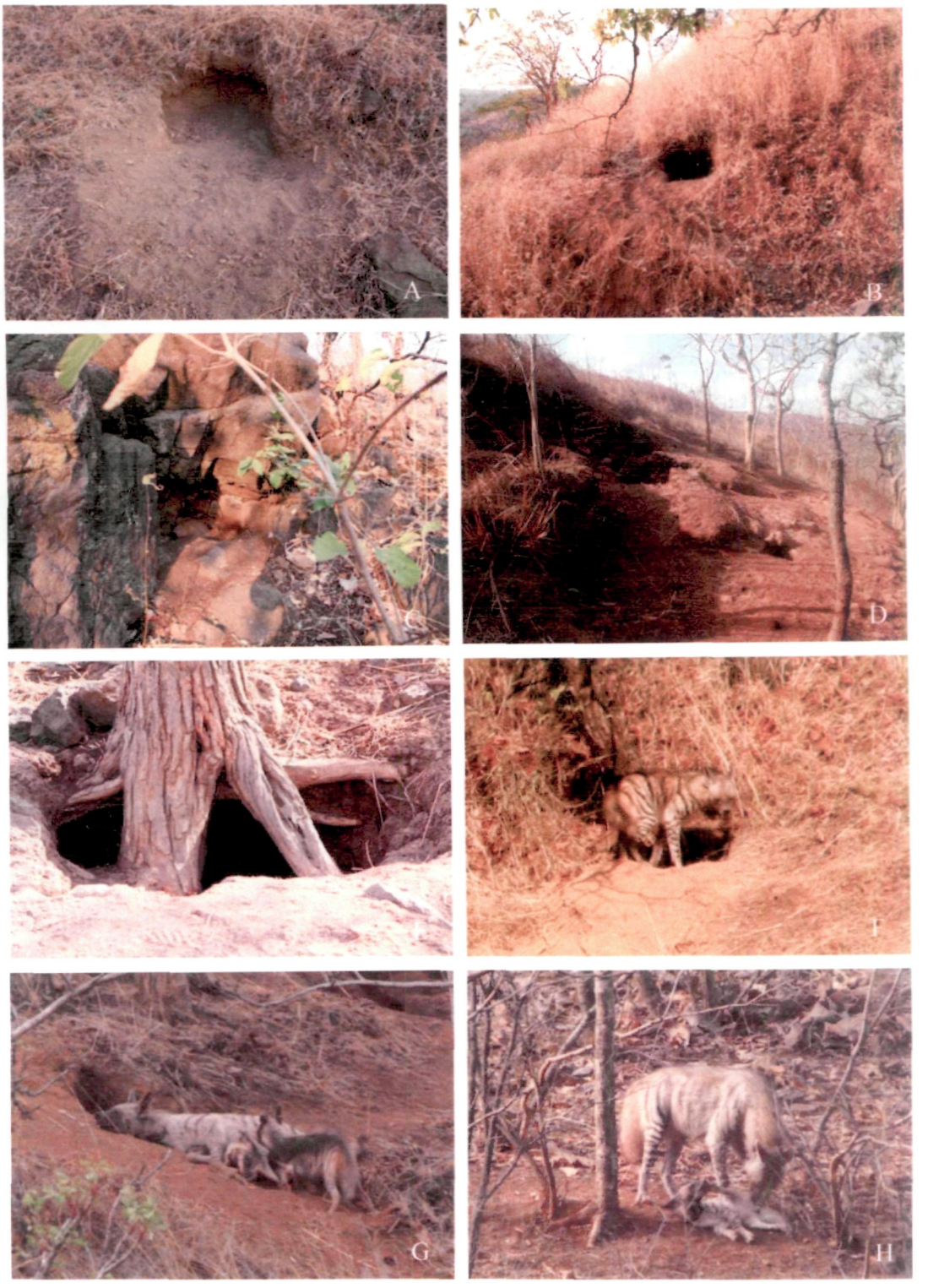

Fig. 6.6: Types of construction used by striped hyenas in different occasions, A - sandy resting site, B - sandy resting den, C - rocky resting site, D - rendezvous site, E - resting den under three and F – a newly constructed den by hyena where pups were given birth. G - A lactating striped hyena in a usual lactation posture and H - a mother striped hyena cleaning a young one near den.

Fig. 6.7: A rocky big cave in eastern GNPS (A), used as permanent den site by striped hyena. An abundant resting site (B) of striped hyena with high grass cover.

Fig. 6.8: Pasting of striped hyena showing lipid-rich white secretion and watery black secretion (A). A fresh striped hyena pasting on a shrub stem on a forest trail (B) located in western GNPS.

6.4 Discussion

The striped hyenas are predominantly nocturnal throughout their range (Kruuk, 1976), this could be to protect from day time heat as they are mainly distributed in dry areas. Apart from being an important water conservation strategy, nocturnal behavior may have evolved as a means of reducing competition with the other dominant scavengers in the ecosystem, the vultures, which are exclusively diurnal (Houston, 1979).

The striped hyena is one of those groups of animals, which has a distinctive feature of digging dens. The den site plays an important role in the daily life of animals' activity and in many other activitys of life like breeding, rearing of young ones and protection from competitors and large predators.

All the hyena species keep their pups in hole in the ground, and although the entrance to these dens may be large, the dens quickly narrow down into tunnels 30-50 cm high and 50-60 cm wide (Mills, 1989), which are only large enough for the pups to enter. The den provides ideal refuge for the pups during the long periods when adults are absent. Around an extended period of 15 months that pups are attached to the den and pups are weaned till as late as 12-15 months of age (Mills, 1983). In GNPS striped hyena were observed to raise their pups only in sandy dens with usually small opening about 40-50 cm high and 50-60 cm wide, except in two cases where rocky dens were used on very steep hill slops, in which same female striped hyena kept pups (around two weeks old) for only few

days. That rocky den was very narrow around 120 cm wide and only 15-20 cm high.

Although, the striped hyena uses both types of dens sandy as well as rocky, but sandy dens are more preferred, may be because they are easy to dig as per the requirement. Most of the time pups were kept in sandy dens and rocky dens or caves usually used by adults for resting and hiding in day time. They preferred hilly habitat for denning and resting usually in the middle of the hill slops and also specific directions, as most of them were found facing north, north-east and north-west, suggesting that they were avoiding direct sun light. Resting sites were generally open ground or shallowly dug so shrub density was found higher than the den sites, which make them easy to hide.

The striped hyena may actively seek out relatively heavy vegetative cover or rocky depressions, particularly large caves, for resting (Rosevear, 1974; Kruuk, 1976; Rieger, 1979a; Leakey et al., 1999; Wagner, 2006). Where larger caves are not available, the resting sites used by striped hyenas are generally not revisited, although they frequently choose sites very close to those used previously (Kruuk, 1976; Wagner 2006). In GNPS the striped hyena does rest relatively dens shrub and grass cover to hide. Shrub density was found higher than the tree density at resting sites. Large caves were found to be used mainly for resting at day time on regular basis. One big rocky cave was observed in Jasadhar range of GNPS,

which was used by four adult hyenas together. In Dedakdi range also, two adult hyenas were observed at a medium sized rocky den.

Greater part of the day, hyenas spend in resting and sleeping and become active usually before one hour of dusk and after complete darkness they go for forage trip. In the mid time they do clinging and cleaning and lactating female lactate their pups outside the den.

Inclusive fitness takes place (that increases the reproductive successes by helping the other individuals of co-specifics or relatives as self were not in the condition to reproduce by some conditions) in the striped hyena as pups of earlier litter help mothers in rearing the newly born pups. They bring food to den for pups, and also give protection to them. This type of behavior could be to increase the reproductive success to maintain the population in low density animals.

Some denning behavior in hyenas is different. In the case of brown hyena (*Hyaena brunnea*) only one litter of pups was found to be reared in most of its den, although occasionally (3 out of 12 dens observed) two females raised their pups simultaneously at the same den (Mills, 1983). While in case of spotted hyena (*Crocuta crocuta*) denning was observed usually communal i.e. being used simultaneously by several females with pups of varying age. The mean of 15 brown hyena litter was 3 (range 1-4), whereas in spotted hyena no female was observed to have more than two pups (Mills, 1989). Only one litter of pups was

observed in most striped hyena den in GNPS, and occasionally (1 out of 8 dens observed) two females raised their pups together at the same den. The mean litter size of striped hyena was found 3 (range 2-4).

Brown hyenas were found to regularly carry carcasses with meat back to den for the pus to eat, whereas spotted hyena do not do so. The milk diet of brown hyena pups, therefore, is supplemented from about 12 weeks of age with meat, whereas spotted hyena's pups obtain a substantial amount of meat only when they are 9-12 months old and stay early to accompany foraging adults (Mills 1989). Pups of striped hyena in GNPS were also observed to have milk diet supplemented by meat at the age of 3 months. In contrast the solitary foraging behavior and scavenging mode of life of striped hyena only allows the individuals, whenever they get chance to eat from the kills of natural predators and carcass of dead animals. Therefore, to avoid competition with the natural predators and other competitors, they prefer to take pieces of carcass with meat back to the den site. So they cannot meet the increased demand of lactation to their pups. Therefore, milk diet of striped hyena pups gets supplemented with the meat at early stage. And by providing additional nourishment to their pups, striped hyena can raise large litters compared to spotted hyenas.

Although, vocal system of striped hyena is difficult to classify because they are graded and linked by intermediates, ever then five vocalizations of striped hyena

in GNPS have been identified compare to eight in brown hyena (Mills 1989) and twelve in spotted hyena (Kruuk, 1972; Mills, 1989).

Chemical communication is also observed in striped hyena as has been also found in other hyenas (Kruuk, 1972; Mills et al., 1980). Pasting is unique to the family Hyaenidae. This occurs chiefly as a means of communication. They pest through anal gland secretions onto grass stalks or small shrubs stem. Moreover, pasting consists of two distinct components; a long-lived, lipid-rich white secretion and a short lived, watery black one (Fig. 6.8). Also in the case of brown hyena pasting consists of two distinct components; long-lived and short lived. Whereas pasting of spotted hyena consist of long-lived component only (Mills et al., 1980).

Two hyaenids, the spotted hyena and the brown hyena have extensively studied (Kruuk, 1972; Mills, 1978, 1984, 1989) compare to striped hyena. Although in very recent years little work was conducted on behavioral ecology in some habitat of its distribution (Wagner, 2006), there are large gaps in our understanding of many aspects of their sociecology. The mating systems in particular are imperfectly understood. Furthermore, their appear to be several options individual can choose, for example, males can be nomadic or belong to a group, and it is not known under which conditions these options are chosen. For this, long-term studies on known individuals are essential. Studies on more habitats would be valuable for learning the extent of behavioral flexibility of the species. Of the four members of Hyaenidae the striped hyena is the least known even though it has the

widest distribution range (Kruuk, 1976; Rieger, 1979; Wagner, 2006). Studies on this species are urgently needed, both to help in its conservation and to further investigate the effects of diet and food dispersion on behavior and social organization.

CHAPTER- 7

HABITAT SUTABILITY MODELLING USING REMOTE SENSING AND GIS

7.1 Abstract

Application of remote sensing and Geographic Information System (GIS) as a tool has assumed immense significance in habitat suitability modelling for various wildlife species. Models are now widely used in conservation ecology and wildlife management. This study evaluated habitat suitability for striped hyena (*Hyaena hyaena*) in Gir National Park and Sanctuary (GNPS), India. The satellite imagery and topographic maps were used to generate spatial data of different variables *viz.*, forest type, forest density, measures of proximity to disturbances (road, railways and settlements) and water. A digital terrain model was used to create slope, aspect, elevation and GPS location of animal's presence were used in a "binomial multiple logistic regression (BMLR)" model in striped hyena habitat suitability analysis. Results indicated that 1108.65 km^2 (78.51%) of GNPS area is highly suitable to suitable for striped hyena. We concluded that GNPS is appropriate as important conservation area for striped hyena in India.

7.2 Introduction

An understanding of the relationship between spatial distribution of animals and their habitats plays an important role in conservation and management of threatened species (Lecis and Norris, 2003). Remote sensing and Geographic Information System (GIS) can be used as tool for getting information about the

habitat preference of the wildlife species. Remote sensing and GIS also help in monitoring areas of land for their suitability to wild species, through integration of various habitat variables of both spatial and non-spatial nature (Davis et al., 1990). The outputs of such models are usually simple, easily understandable and can be used for the assessment of environmental impacts or prioritization of conservation efforts in a timely and cost-effective manner (Kushwaha et al., 2004; Zarri et al., 2008). Striped hyena (*Hyaena hyaena*) belongs to Hyaenaidae family and is one of the four extent species found in the world and the only species found in India. Striped hyenas are scavenger by habit (Prater, 1971; Kruuk, 1976; Boitani and Bartoli, 1986; Hofer, 1998 and MacDonald, 1984). They seek their food by scent. All in all, the animal is built neither for attack nor for swift pursuit of prey. Its structure fits its particular mode of life, which is to feed on prey killed by other animals (Prater, 1971).

Striped hyena occupy a range of habitats and may settle where ever they get sufficient food supply, adequate cover and access to water (Kruuk, 1976). The striped hyena generally favors open or thorn bush areas in arid to semi-arid environments (Prater, 1971, Rosevea,r 1974; Kruuk, 1976; Rieger, 1978; Leakey et al., 1999; Wagner, 2006), where water is available within 10 km (Rieger 1979a), and favors large caves for resting (Kruuk, 1976; Rieger, 1979a; Leakey et al., 1999) and avoid open desert and dense thickets and forests (Rosevear, 1974; Rieger, 1979a; Heptner and Sludskii, 1980). Rocky ridges are used for dening if area is hilly and undulating (Kruuk, 1976). The striped hyena is distributed over

north Africa, Arabia, Iraq, Iran, Afghanistan, Pakistan and much part of India (Prater, 1971; Kruuk, 1976; Boitani and Bartoli, 1986; Hofer and Mills, 1998; MacDonald, 1984; Alam et.al, 2009).

Despite, striped hyena's vast distribution, population is declining in many places due to persecution and hunting for utilization. Ecological factors may also be contributing to the decline, including dimifnishing food stocks and competition with leopards over shelter (Heptner and Sludskij 1980). In the IUCN red list of threatened species, striped hyena is listed as near threatened. In India hunting is prohibited under the Wildlife (Protection) Act 1972, Schedule-III. The striped hyena occurs at low population densities throughout its distribution range. Its habitats continue to shrink and fragment globally under an ever-increasing anthropogenic pressure. Very few studies have been done from Africa (Kruuk, 1976; Leakey et.al, 1999; Wagner, 2006), Israel (MacDonal, 1978; Bouskila, 1984; Ilani 1975, Kerbis-Peterhans and Horwitz, 1992; Skinner and Ilani, 1979), India (Davidar, 1990, Alam, 2006; Alam et.al, 2009).

Although, striped hyenas are important member of the ecosystem yet their population is globally declining (Hofer and Mills, 1998) to the verge of extinction in several ranges (Kruuk, 1976). The striped hyena is considered as data deficient and threatened animal in several areas of its geographical range (Hofer and Mills, 1998). Hence, there is an urgent need for research on biology and ecology of this species. The present study is a step in this direction.

7.2.1 Geospatial technology for habitat suitability modelling

Habitat suitability evaluation is the first step towards meaningful wildlife conservation (Kushwaha, 2002). Geospatial technology including remote sensing, GIS and global positioning system (GPS) provide factual data and information for determining habitat quality (Schamberger and Krohn, 1982). A suitability index indicates the degree of suitability of the area for a particular species. The higher the values the better are the chances for the survival of species.

The concept of wildlife habitat analysis started with the development of habitat evaluation procedure (HEP) by the U.S. Fish and Wildlife Service. Evaluation of wildlife habitats based on ecological principles is well-established in USA in connection with environmental impact assessments, where the aim was to ensure that appropriate consideration is given to wildlife in the development planning process (U.S. Fish and Wildlife Service, 1981). At the same time, there has been considerable pressure for the use of standardized procedures for habitat evaluation, both for economical as well as ecological reasons among various organizations and professionals. Encouraged by the results, Bright (1984) used remotely sensed data along with other ecological parameters to assess the habitat of elk (*Cervus canadensis*), whereas Hill and Kelly (1987) used it for kangaroo (*Macropus giganteus*). Later on Landsat image classifications were used in modelling for predicting the nesting sites of American kestrel (*Falco sparverius*) (Lyon, 1983) and during the same year Harris (1983) used visual Landsat image

classification as an effective tool in re-introduction programme of the white oryx (*Oryx leucoryx*). In India, the use of geospatial technology for analyzing the "habitat suitability index" started during the late 1980s. In 1986, Parihar et al. used remotely sensed data from Landsat for habitat evaluation of Indian one-horned rhinoceros, while Roy et al. (1995) used this technology for habitat suitability analysis of *Nemorhaedus goral*. Similarly, Porwal et al. (1996) used remote sensing data for evaluating the habitat for sambar (*Cervus unicolor*) in Kanha National Park.

Mongkolswat and Thirangoon (1998) identified potential habitat sites for 7 wildlife species in Northeast of Thailand. The geospatial technology was widely used for habitat suitability analysis of various wild animals. Study on suitable habitat for rhinoceros in Kazhiranga National Park (Kushwaha et al., 2000) and for mountain goat in Rajaji National Park (Kushwaha et al., 2001). Recently, Kalra (2005), Unial (2005) and Habib et al., (2010) used remote sensing and GIS for the habitat evaluation of great Indian bustard, lion in desert National Park and on ungulates in Pathri Rao watershade respectively.

7.2.2 Binomial multiple logistic regression

Application of binomial multiple logistic regression (BMLR) is a statistical technique for predictive modelling. Binomial logistic regression is a form of regression which is used when the dependent variable is dichotomous and independent variables are continuous. For BMLR statistical analysis, statistical

package for the Social Sciences (SPSS) has been widely used. The BMLR applies maximum likelihood estimation after transforming the dependent variable into a logit variable. In this way the binomial multiple logistic regression estimates the probability of a certain event occurring. Habitat models using presence–absence (dichotomous dependent variable) data and binomial multiple logistic regression is useful in formalizing the relationship between environmental conditions (independent habitat variables) and species habitat requirements. Thus quantifying the amount of potential habitat available. In India Kushwaha et al. (2004), Aditya (2004), Quadri (2004), Braunisch et al. (2008), Zarri et al. (2008) and Imam et al. (2009) have used BMLR to work out the habitat suitability for *Cervus unicolor* and *Muntiacus muntjac* at Ranikhet, muntjac in Binsor Wildlife Sanctuary, tiger in Corbett Tiger Reserve, edge effect on two population of capercaillie (*Tetrao urogallus*) and Nilgiri laughingthrush (*Garrulax cachinnans*) in Western Ghats and tiger in Chandoli National Park, respectively.

7.3 Data and methodology

The study was carried out in three phases. In the first phase field survey was done to collect data on striped hyena's presence. In the second phase collection and processing of collateral and satellite data was done to create spatial data base on Forest canopy density, forest type, aspect, slope, elevation and other distance attributes. In the third geospatial modeling was carried out. In the present study *ERDAS Imagine 9.1*, *ArcGIS 9.3*, *ArcView 3.2a* and *SPSS-10*, computer software were used for data processing and GIS analysis.

The field surveys were carried out between 2006 to 2009. For collecting data on presence of striped hyena from the study area "opportunistic" sampling was made. Since, absence of a species cannot be considered as being as certain as presence (Schroder and Richter, 2000), wherever direct and indirect evidence (foot print, scats, den etc.) was obseved GPS location in geographic lat/long and other habitat attributes were recorded. Absence point data was generated by an expert field experience of four years in the field and on the basis of different habitat attributes and parameters.

Satellite data of Landsat-TM dated 15th May 2009, path-row: 149-45 was downloaded from http://glovis.usgs.gov/. The digital elevation model (DEM) data of shuttle radar topographic machine (SRTM) was downloaded from the website http://www.srtm.csi.cgiar.org/, http://www.srtm.usgs.gov/ and imported to ERDAS Imagine 9.1 for producing the maps of aspect, slope and elevation. A map with various attributes of GNPS with high resolution was procured from Office of the Deputy Conservator of Forest, Wildlife Division Sasan-Gir, Gujarat, and co-registered using geometric correction techniques. This data was re-projected into Universe Transverse Mercator (UTM) World Geodetic System-84 (WGS 84) projection for further analysis. A study area of interest (AOI) was built around the park boundary to produce a rectilinear map and information on roads, railway, water point, temporary settlements, settlements villages and park boundary were extracted.

The geo-coded FCC of Landsat-TM dated 15th May 2009 (Fig. 7.4) was digitally analyzed. The forest cover and land use map (habitat map) of the study area was prepared through digital analysis of satellite data using supervised maximum likelihood classification technique. Supervised classification is a procedure for identifying spectrally similar areas on an image by identifying 'training' sites of known targets and then extrapolating those spectral signatures to other areas of unknown targets. Supervised classification relies on the *a priori* knowledge of the location and identity of land cover types that are in the image. This can be achieved through fieldwork, study of aerial photographs or other independent sources of information. Training areas, usually small and discrete compared to the full image, are used to "train" the classification algorithm to recognize land cover classes based on their spectral signatures, as found in the image. The maximum likelihood classifier (MLC) assumes that the training statistics for each class have a normal or 'Gaussian' distribution. The classifier then uses the training statistics to compute a probability value of whether it belongs to a particular land cover category class. This allows for within-class spectral variance. In this the image analyst uses a priori knowledge to weight the probability function. The MLC usually provides the highest classification accuracies.

Normalized difference vegetation index (NDVI) was used for preparation of forest density map. The NDVI values were grouped into four canopy density classes *viz.*, <10% (non-forest), 10–40% (open), 40–70% (medium) and >70% (dense).

Image elements like tone, texture, shape, size, shadow, location and association were evaluated for this purpose. NDVI is a method of measuring and mapping the density of green vegetation. For its measurement scientists use satellite sensors that observe the distinct wavelengths of visible and near-infrared sunlight which is absorbed and reflected by the plants, then the ratio of visible and near-infrared light reflected back up to the sensor is calculated. The ratio gives a number from minus one (−1) to plus one (+1). An NDVI value of zero means no green vegetation and close to +1 (0.8–0.9) indicates the highest possible density of green leaves. The 'normalized difference vegetation index' is calculated by the formula: NDVI = (IR−R)/ (IR + R), where IR = infrared and R = red. Habitat suitability analysis requires generation of an accurate database on various life support systems as well as potential disturbance factors affecting the habitat. The slope, aspect and elevation maps were generated from topographic maps through scanning and digitization using *Arc View 3.2a*. Continuous surfaces of distance from drainage, tourism roads, state highways, railway, water points, temporary settlements (ness) and settlement villages were generated for proximity analysis. All the input layers were co-registered with sub-pixel accuracy.

Variables (Table 7.1) like aspects, elevation, slope, distance from drainage, distance from tourism roads, distance from state highways, distance from water points, distance from temporary settlement, distance from settlement villages, forest type and forest (canopy) density were selected. All the input layer maps are shown from Fig. 7.2 to 7.14.

GPS locations of striped hyena's presence/absence were fed into the GIS environment were attached as attributes to all the locations. All the independent variables like slope, aspects and distance from drainage, tourism roads, state highways, temporary settlement, settlement villages were transferred into raster themes and used for further analysis. Values for forest type and forest canopy density were recorded and specified as categorical variables. The points of striped hyena detection were then intersected with all the input layers to produce the habitat use-environmental variables matrix. This worksheet was employed for further statistical analysis. Here, cases of striped hyena evidences (direct and indirect) were taken as being present or absent of the species. The coefficients derived from BMLR were used to integrate all layers to arrive at the probability/suitability maps. Suitability map was further categorized into four classes highly suitable, suitable, moderately suitable and least suitable.

Table 7.1: List of spatial layers used for striped hyena habitat suitability.

Name of layer	**Layer format**	**Source**	**File type**	**Software used**
Aspect	Polygon	GIS derivative	Image file	*ERDAS IMAGINE 9.1*
Slope	Polygon	GIS derivative	Image file	*ERDAS IMAGINE 9.1*
Elevation	Polygon	GIS derivative	Image file	*ERDAS IMAGINE 9.1*
Drainage	Line	Satellite imagery	Shape file	*ArcView 3.2a*
State highway	Line	Map	Shape file	*ArcView 3.2a*
Tourism road	Line	Map	Shape file	*ArcView 3.2a*
Railway	Line	Map	Shape file	*ArcView 3.2a*
Temporary settlement	Point	Map	Shape file	*ArcView 3.2a*
Settlement Village	Polygon	Map	Shape file	*ArcView 3.2a*
Water point	Point	Map	Shape file	*ArcView 3.2a*
Forest type	Polygon	Satellite imagery	Image file	*ERDAS IMAGINE 9.1*
Forest canopy density	Polygon	Satellite imagery	Image file	*ERDAS IMAGINE 9.1*

Table 7.2: Result of logistic regression analysis.

Variables	**B***	**SE**	**Wald**	***df***	**Sig.**	**Exp(B)**
Aspect	-0.002	0.002	1.058	1	0.304	0.980
Elevation	-0.009	0.004	4.63	1	0.031	0.991
Slope	-0.051	0.047	1.170	1	0.279	0.951
Distance to drainage	-0.487	0.134	13.231	1	0.000	0.651
Distance to state highway	0.211	0.092	5.280	1	0.022	1.235
Distance to tourism road	0.212	0.077	7.548	1	0.006	1.236
Distance to railway	-0.068	0.067	1.010	1	0.315	0.935
Distance to temporary settlement	-0.271	0.191	2.011	1	0.156	0.763
Distance to settlement village	0.827	0.183	20.502	1	0.000	2.286
Distance to water point	-0.195	0.115	2.862	1	0.091	0.823
Forest density (>10%)	1.229	1.088	1.275	1	0.259	3.418
Forest density (10-40%)	4.597	1.665	7.560	1	0.006	97.375
Forest density (40-70%)	2.170	1.222	3.151	1	0.076	8.756
Forest density (<70%)	3.192	60.496	0.003	1	0.958	24.349
Reverine	1.776	1.388	1.638	1	0.201	5.909
Mixed Forest	-7.865	28.567	0.076	1	0.783	0.000
Tectona/Anogeissus-Acacia-Zizyphus	1.293	1.216	1.130	1	0.288	3.645
Acacia-Tectona/Anogeissus	1.941	1.106	3.079	1	0.079	6.963
Acacia-Lannea-Boswelia	1.512	1.441	1.101	1	0.294	4.535
Thorn forest	-1.094	60.457	0.000	1	0.986	0.335
Agriculture	10.932	85.485	0.016	1	0.898	55930.88
Water body	0.368	1.063	0.120	1	0.729	1.444
Constant	-1.939	1.826	1.127	1	0.288	0.144

* Values used as coefficient.

7.4. Results and Discussion

Habitat suitability for striped hyena in GNPS was analyzed using binomial multiple logistic regression. For modelling, environmental factors (Table 7.2) were used as independent variables and striped hyena evidences (direct/indirect) were considered as Boolean (dependent and intersected).

The computer software uses following formula for analyzing the probability:

$\ln (ODDS) = \ln [\acute{Y}/1-\acute{Y}] = a + bx$

Where, Ý is the predicted probability of the event which is coded with 1 (presence) rather than with 0 (absence), 1- Ý is the predicted probability of the other decision, and x is our predictor value.

The Habitat Suitability Index (HIS) was calculated using following formula:

$$HIS = \left\{ \frac{\{\exp(FD*C)+(FT*C)+(EL*C)+(AS*C)+(SP*C)+(DD*C)+(SHD*C)+(TRD*C)+(RD*C)+(TSD*C)+(SVD*)+(WPD*C)+(Constant)\}}{\{1+(\exp(FD*C)+(FT*C)+(EL*C)+(AS*C)+(SP*C)+(DD*C)+(SHD*C)+(TRD*C)+(RD*C)+(TSDD*C)+(SVD*)+(WPD*C)+(Constant))\}} \right\}$$

Where, exp = Exponential, FT = Forest type, FD = Forest canopy density, EL = Elevation, AS = Aspect, SP = Slope, DD = Drainage distance, SHD = State highway distance, TRD = Tourism road distance, RD = Railway distance, TSD = Temporary settlement distance, SVD = Settlement village distance, WPD = Water point distance, and C = Coefficient value.

The BMLR was used for analysis and coefficients mentioned in table 7.2 were considered as weight for the variables and then "logit" transformation was done to prepare probability map for striped hyena.

Habitat suitability index for striped hyena =

$$\frac{\{\exp(FD(0\text{-}10\%) * (2.170)) + (FD(10\text{-}40\%) * (3.192)) + (FD(40\text{-}70\%) * (4.579)) + (FD(<70\%) * (1.229)) + (FT(RV) * (1.776)) + (FT(MF) * (-1.094)) + (FT(TAZ) * (1.512)) + (FT(ATA) * (1.941)) + (FT(ALB) * (-7.865)) + (FT(TF) * (0.368)) + (FT(AG) * (1.293)) + (FT(WB) * (10.932)) + (EL * (-0.009)) + (AS * (-0.002)) + (SP * (-0.051)) + (DD * (-0.487)) + (SHD * (0.211)) + (TRD * (0.212)) + (RD * (-0.068)) + (TSD * (-0.271)) + (SVD * (0.827)) + (WPD * (-0.195)) + (Constant * (-1.939))\}}{\{1 + \exp(FD(0\text{-}10\%) * (00)) + (FD(10\text{-}40\%) * (00)) + (FD(40\text{-}70\%) * (00)) + (FD(<70\%) * (00)) + (FT(RV) * (00)) + (FT(MF) * (00)) + (FT(TAZ) * (00)) + (FT(ATA) * (00)) + (FT(ALB) * (00)) + (FT(TF) * (00)) + (FT(AG) * (00)) + (FT(WB) * (00)) + (EL * (-0.009)) + (AS * (-0.002)) + (SP * (-0.051)) + (DD * (-0.487)) + (SHD * (0.211)) + (TRD * (0.212)) + (RD * (-0.068)) + (TSD * (-0.271)) + (SVD * (0.827)) + (WPD * (-0.195)) + (Constant * (-1.939))\}}$$

where, exp = Exponential, FD = Forest canopy density, FT = Forest type, RV = Reverine, MF = Mixed forest, TAZ = *Tectona/Anogeissus-Acacia-Zizyphus*, ATA = *Acacia-Tectona/Anogeissus*, ALB = *Acacia-Lannea-Boswellia*, TF = Thorn forest, AG = Agriculture, WB = Water body, EL = Elevation, AS = Aspect, SP = Slope, DD = Drainage distance, SHD = State highway distance, TRD = Tourism road distance, RD = Railway distance, TSD = Temporary settlement distance, SVD = Settlement village distance and WPD = Water point distance.

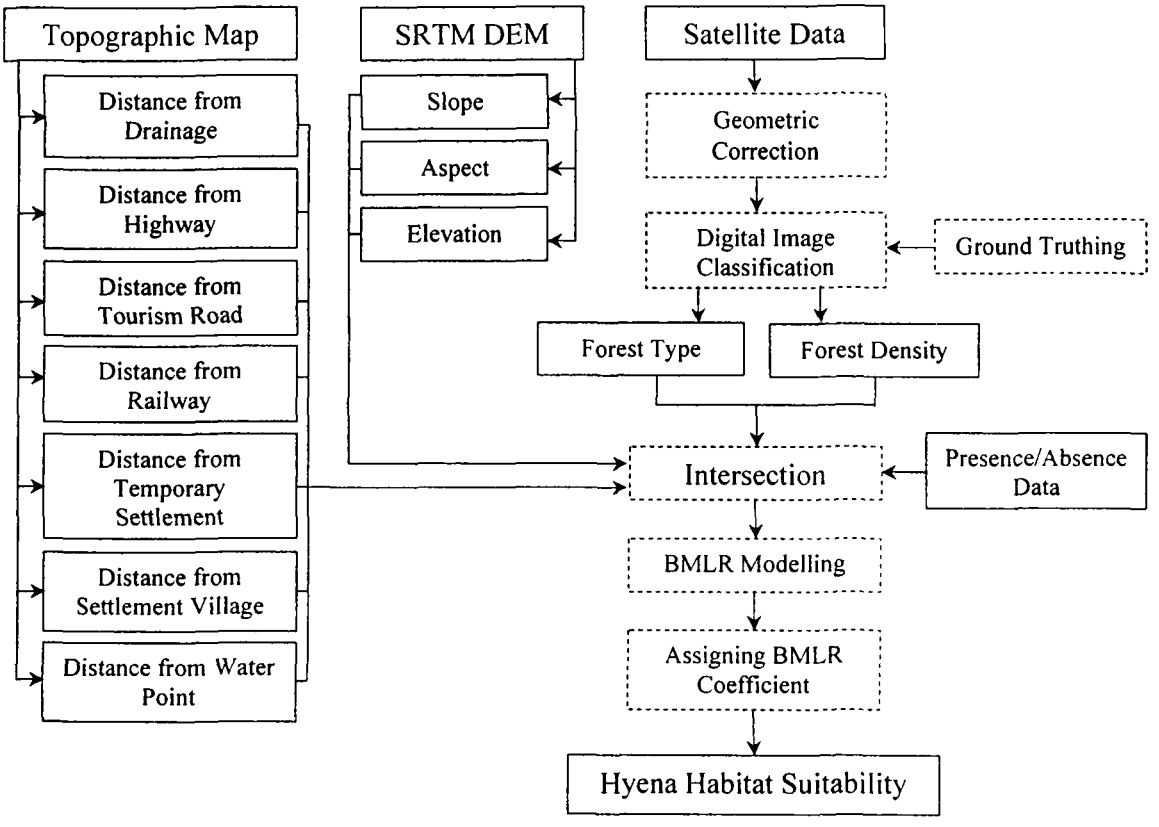

Fig. 7.1: Paradigm of striped hyena habitat suitability modelling.

The overall classification accuracy was done to know the validity of the model. Generally two types of errors enter into modelling procedure; first, the omission and second the commission errors (Lillesand and Kiefer, 2002). For expressing the accuracy error matrix is prepared. In this all non-diagonal elements of the matrix represent errors of omission or commission. Omission errors are correspondent to non-diagonal column elements. Commission errors are represented by non-diagonal row elements. Accuracy assessment is determined by

dividing the total number of correctly classified pixels (sum of elements along the major diagonals) by the total number of reference pixels. Statistically KHAT (K^) is the method of accuracy assessment, where its value ranges between 0 and 1. If value is 1, it means the model is ideal and if its value is 0.89, it means model's accuracy level is 89%.

We also used receiver operating characteristic (ROC) for assessing the accuracy of the model (Fielding and Bell, 1997; Guisan and Zimmermann, 2000; Pearce and Ferrier, 2000; Schroder and Richter, 2000; Osborne et al., 2001). An ROC was obtained by plotting the true positive proportion of correctly predicted occurrences (sensitivity) on the Y-axis against the false positive proportion of correctly predicted absences (specificity) on the X-axis.

The ROC curve is a graphical representation of the trade-off between the false negative and false positive of a test, i.e. its ability to correctly classify cases is measured by the Area Under the ROC Curve (AUC). A ROC curve was generated in order to see the 'strength of conviction' of probability logistic regression scores that a subject (pixel) falls into one category or another (presence or absence). The AUC and its standard error were calculated using a non-parametric approach. The AUC varies from 0.5 (for a chance performance) to 1.0 for a perfect fit (Osborne et al., 2001). The results are reported as AUC ± standard error along with the significance of a test that the area = 0.5, *i.e.* the model result does not differ from chance.

The striped hyena is a one of the least known big carnivore species that play an important role in energy flow in an ecosystem. In India, many parts of its distribution range, its population is reduced and confined only to small patches and among other reasons, habitat depletion is one of the important factors, restricting the population of this species. The present study highlights that extensive field work, sound database, statistical treatment of data, and modelling is helpful in predicting the potentiality of a habitat for striped hyena with acceptable accuracy (Fig. 7.16). The overall classification accuracy of 86.5 percent was observed (Table 7.3), which depict, that model is only 13.5 present away from the ideal. The model performance assessed by the area under the ROC curve was found 0.902 implying that the present model is an effective model (Fig. 7.15).

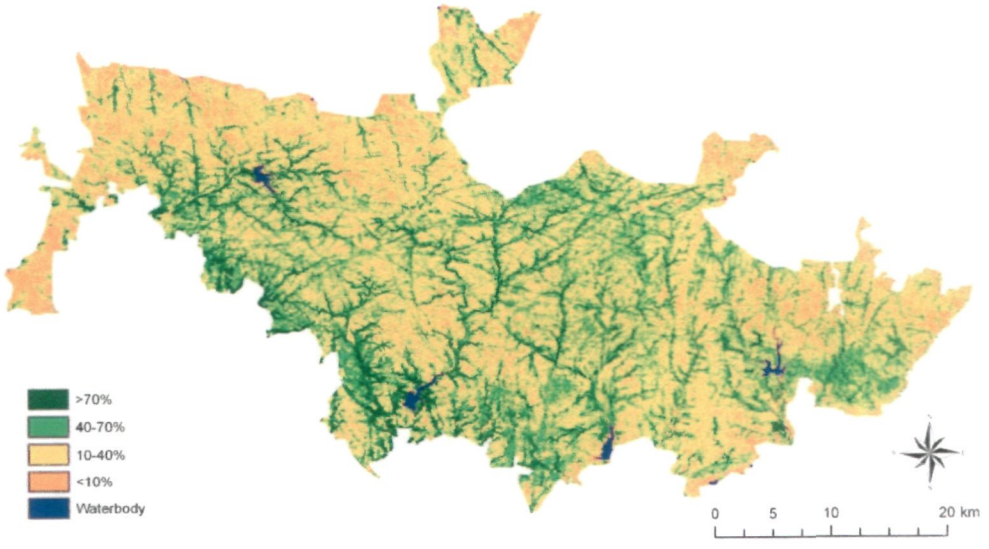

Fig. 7.2: Forest canopy density map of GNPS.

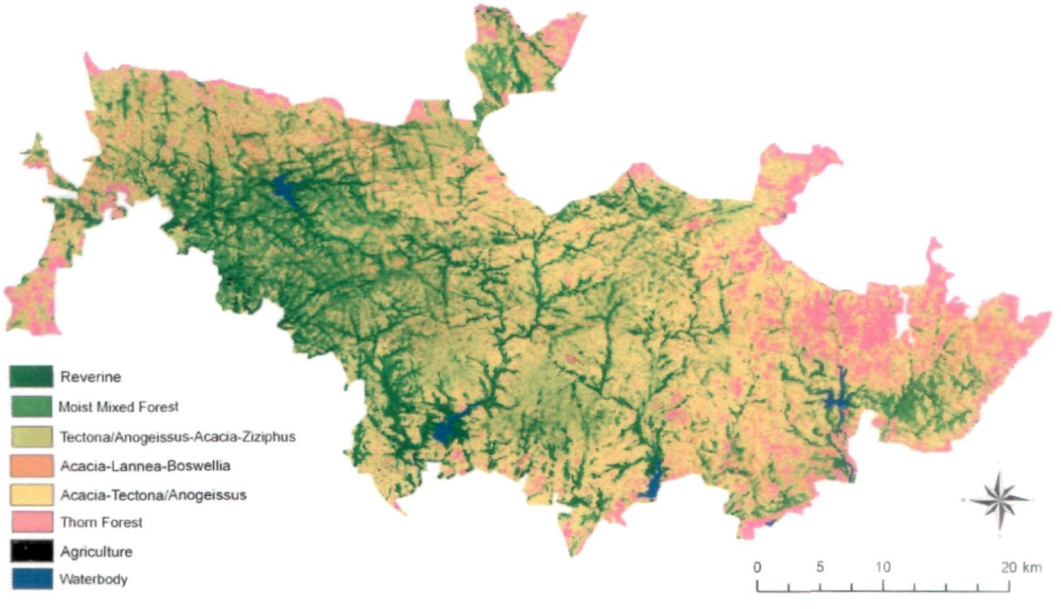

Fig. 7.3: Forest type map of GNPS.

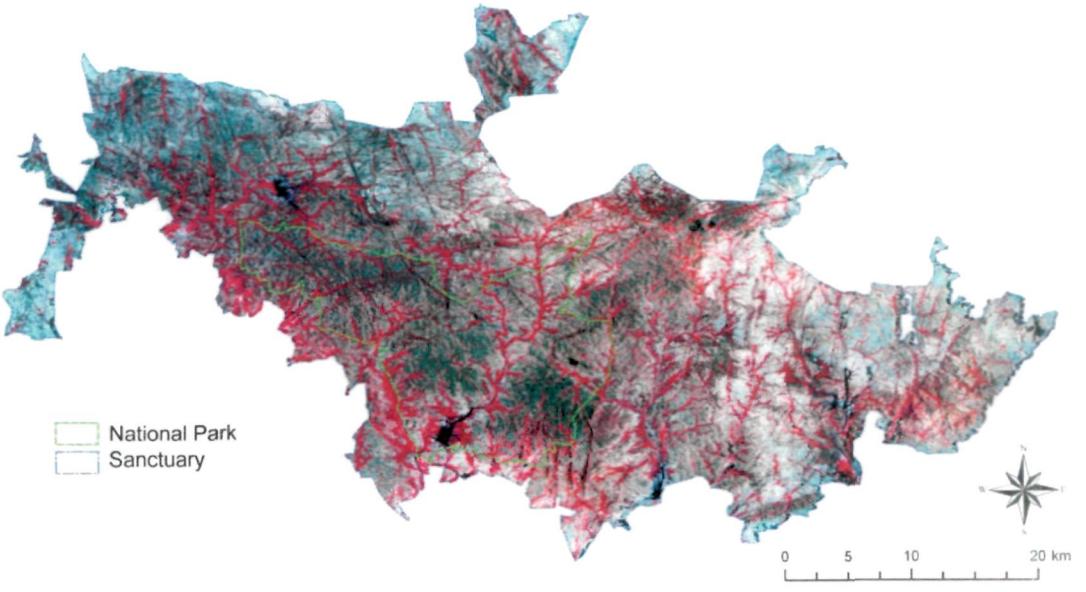

Fig. 7.4: Landsat-TM False Colour Composite of GNPS.

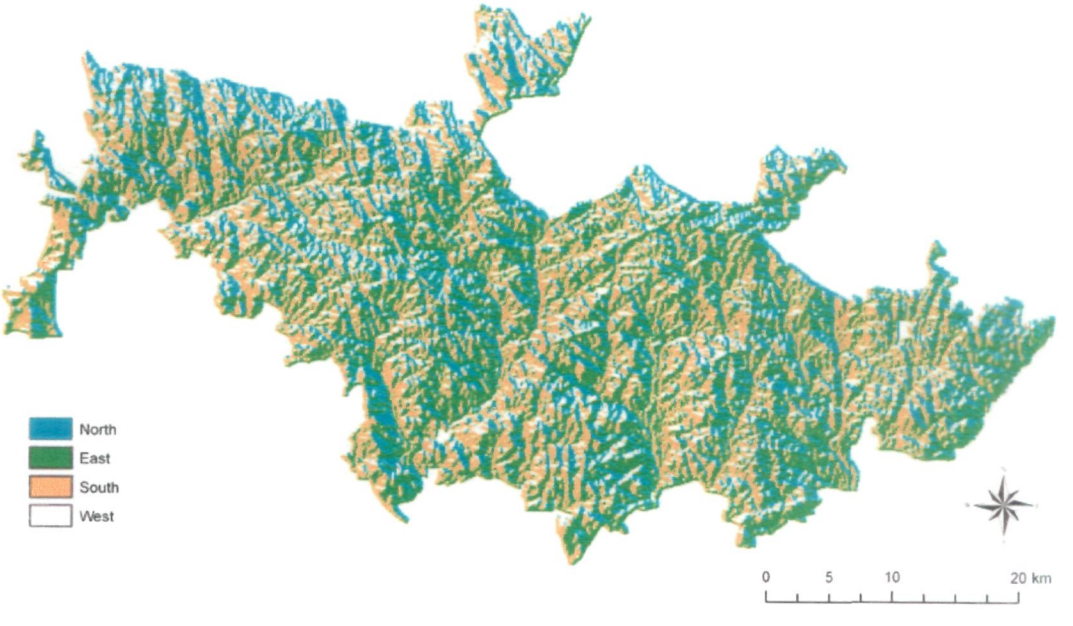

Fig. 7.5: Aspect map of GNPS.

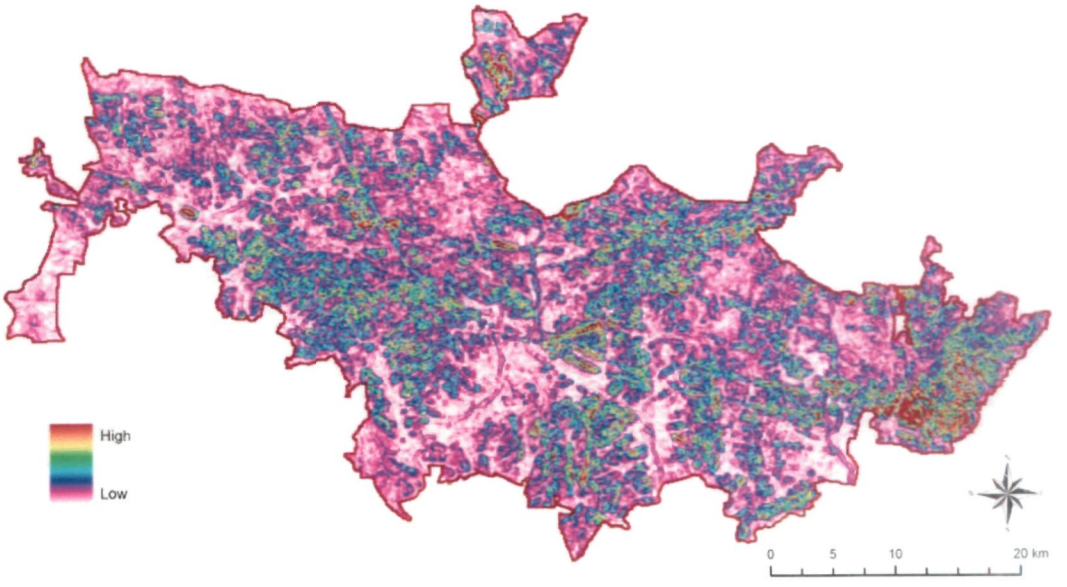

Fig. 7.6: Slope map of GNPS.

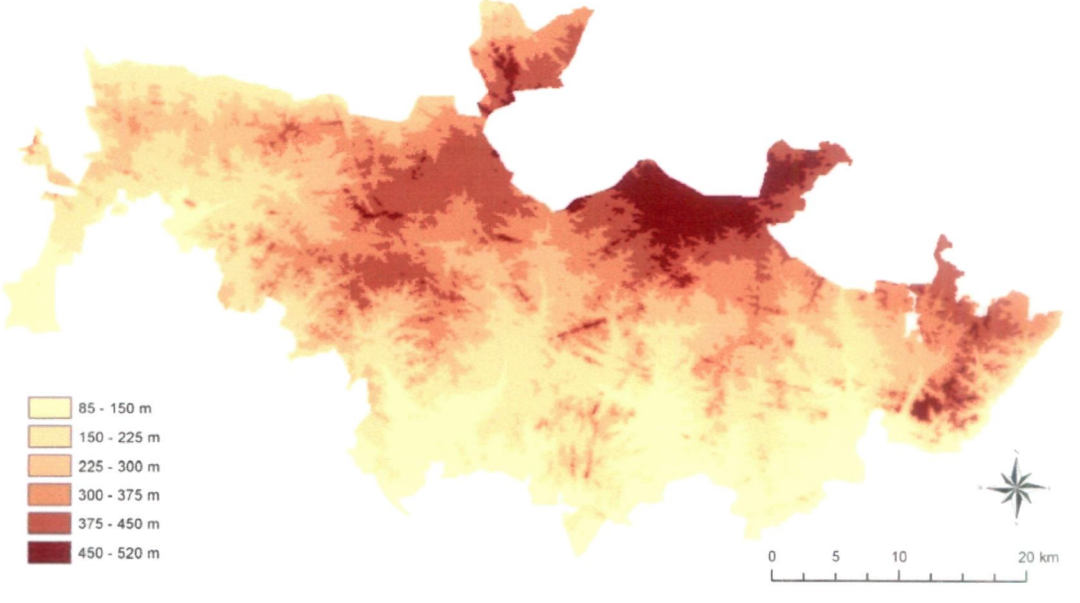

Fig. 7.7: Elevation map of GNPS.

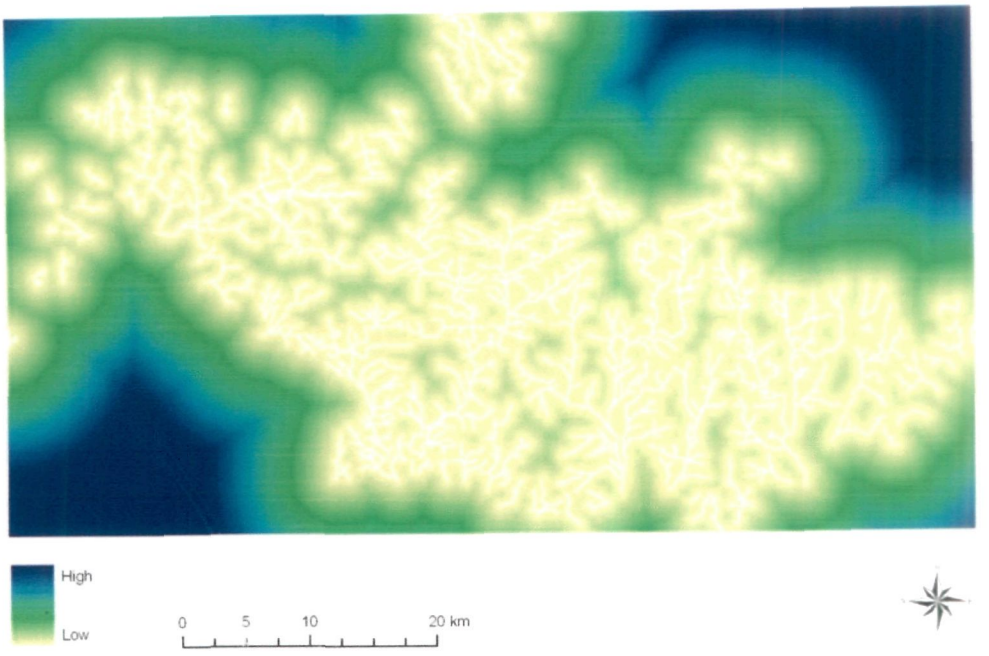

Fig. 7.8: Distance from drainage.

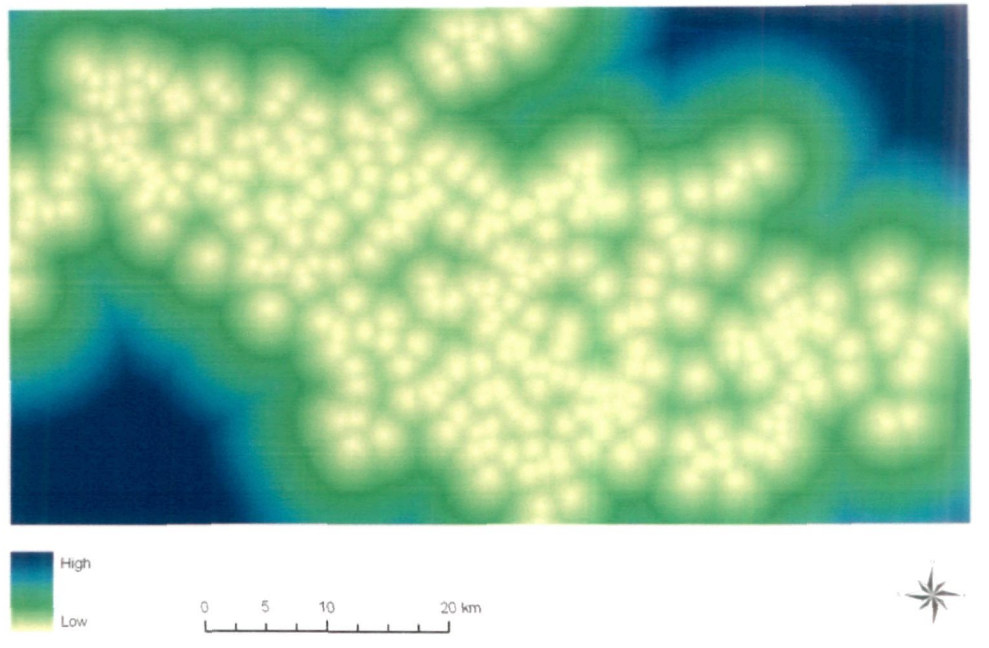

Fig. 7.9: Distance from waterpoint.

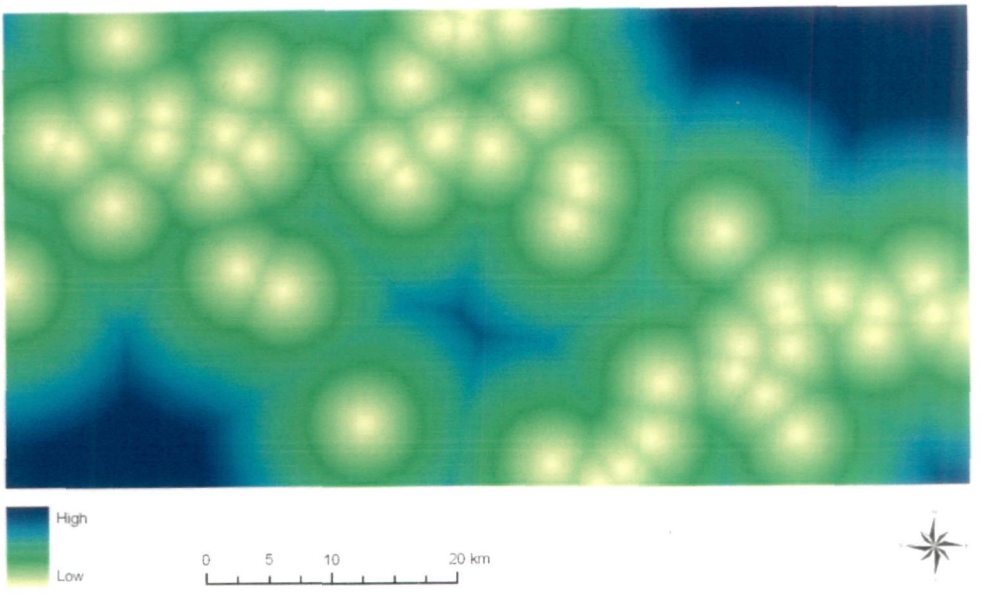

Fig. 7.10: Distance from temporary settlement (Ness).

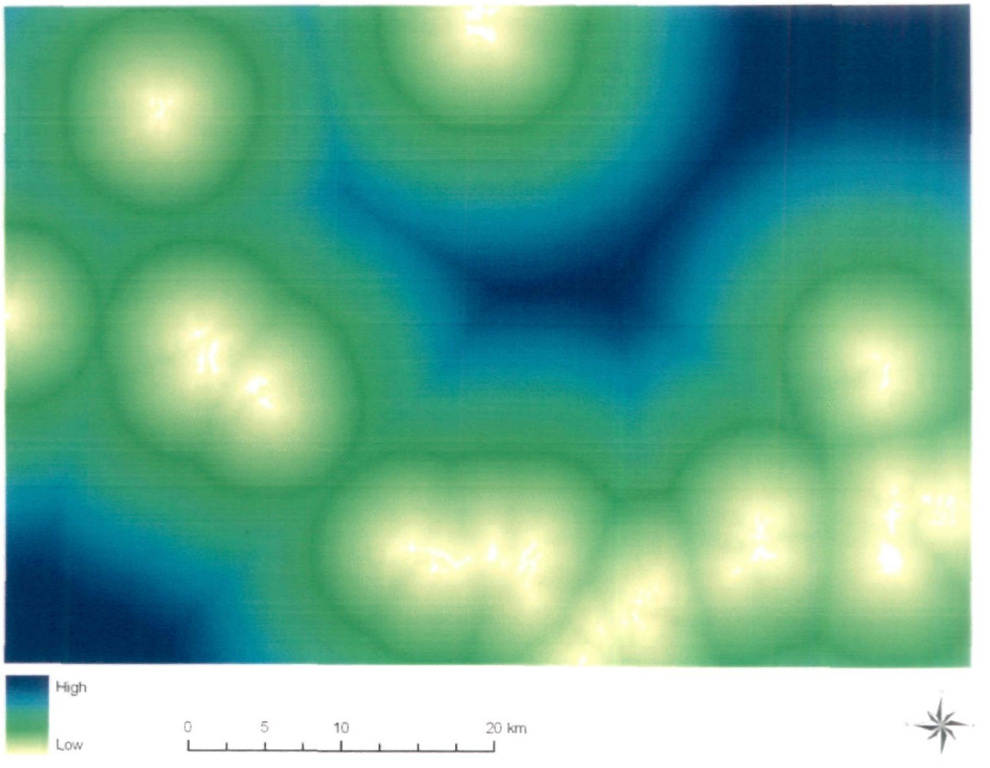

Fig. 7.11: Distance from settlement villages.

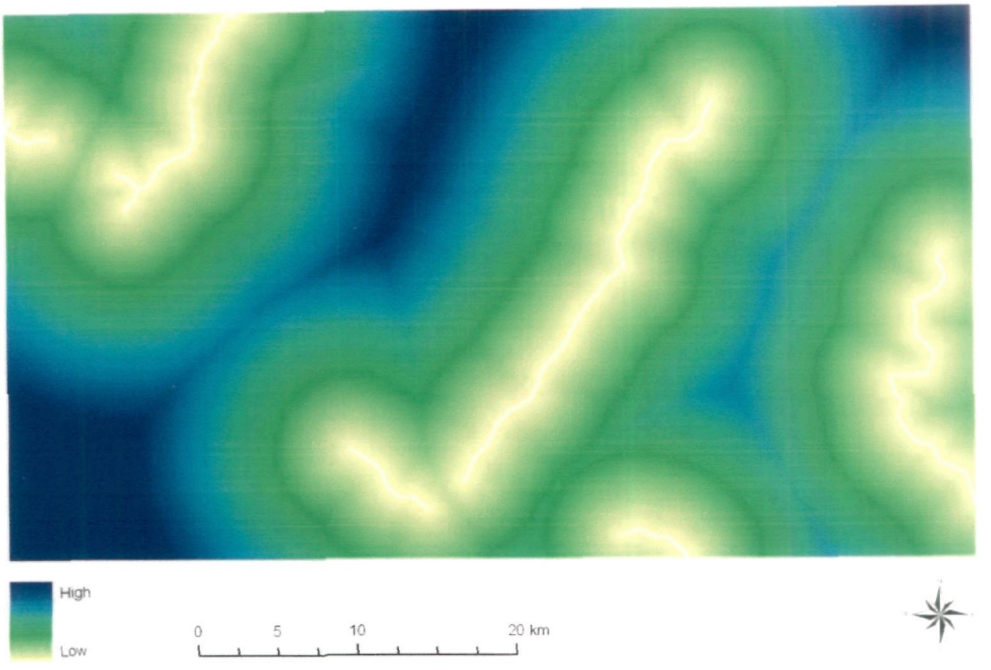

Fig. 7.12: Distance from state highway.

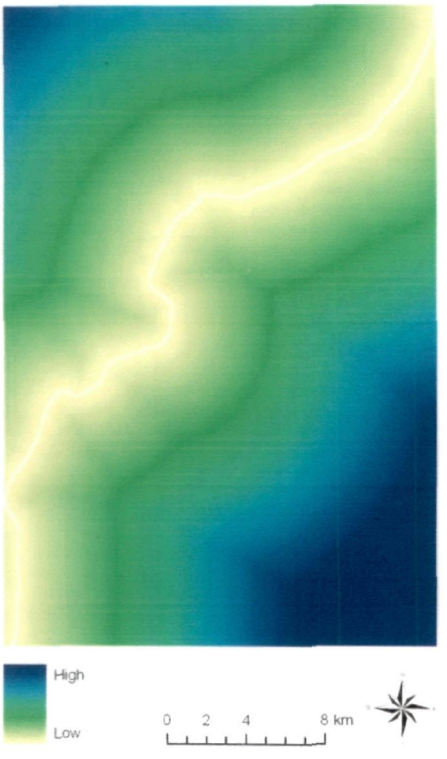

Fig. 7.13: Distance from railway.

Fig. 7.14: Distance from tourism road.

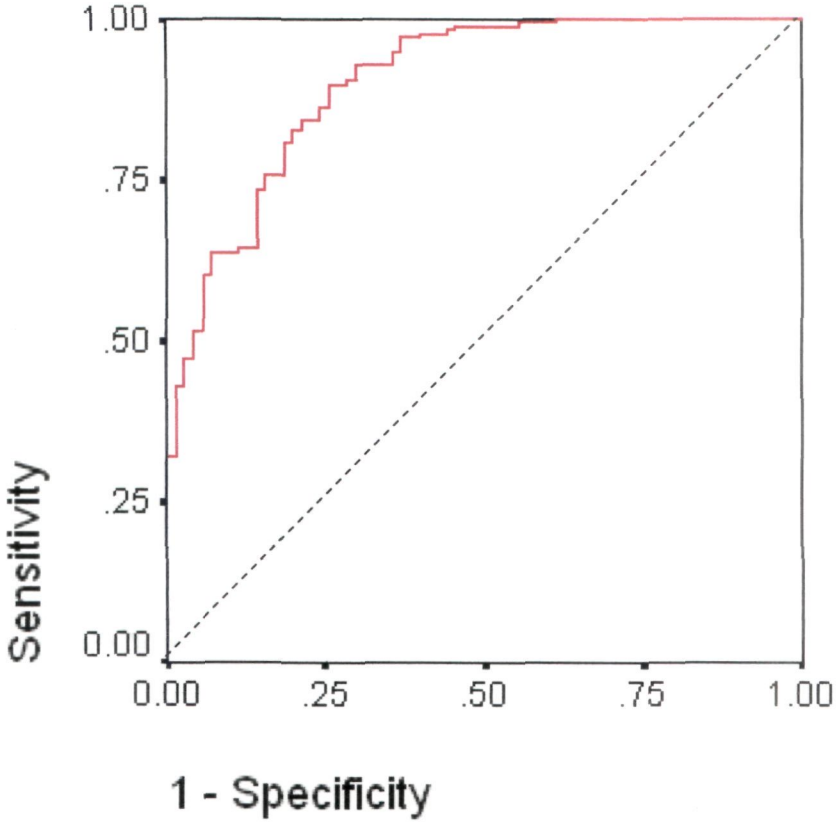

Fig. 7.15: Graph depicting area under ROC curve.

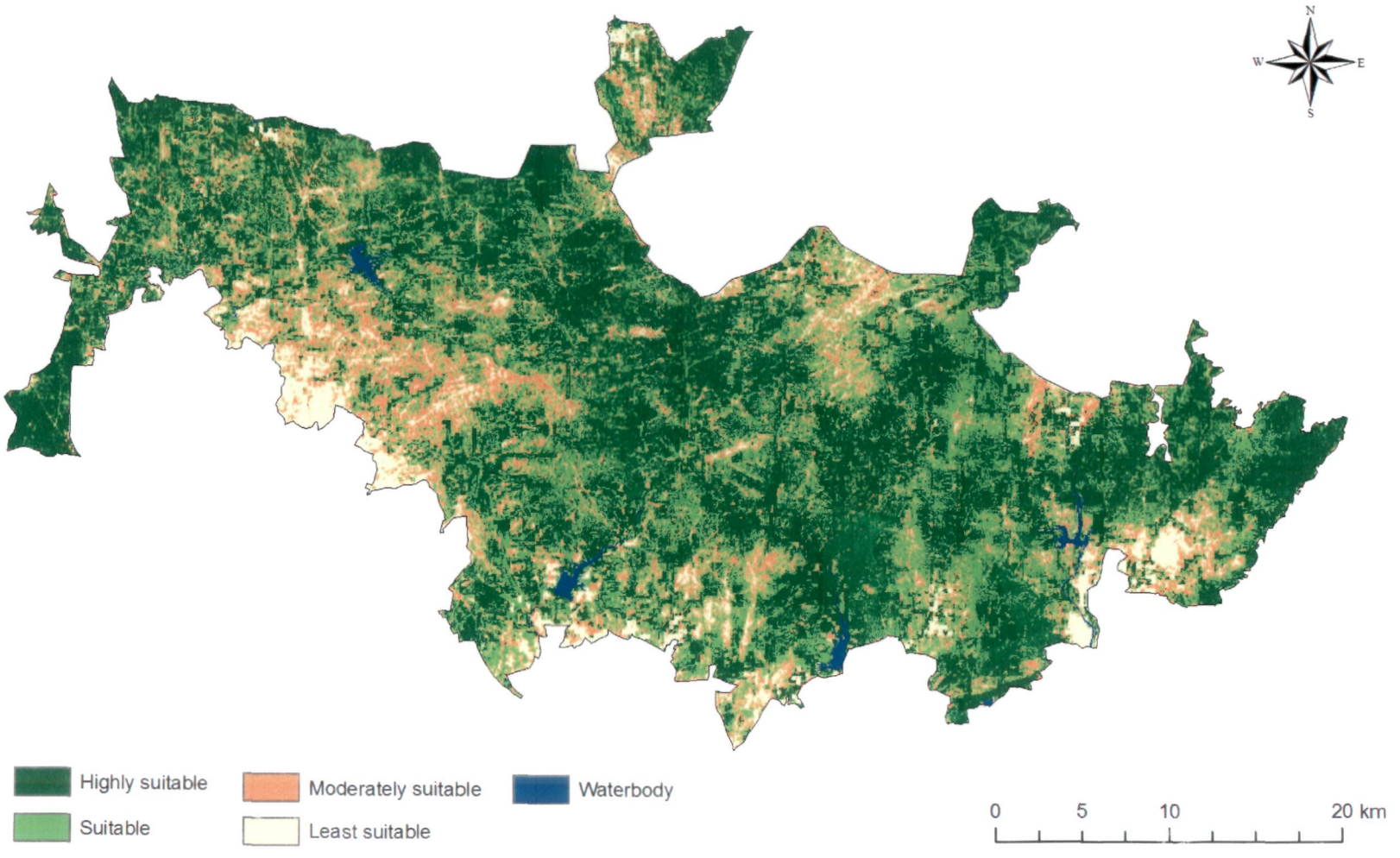

Fig. 7.16: Habitat suitability for striped hyena.

Table 7.3: Classification accuracy for striped hyena modelling.

Observed	Predicted		Percent correct
	Absent (0)	Present (1)	
Absent (0)	44	26	62.9
Present (1)	7	167	96.0
Overall			86.5

Table 7.4: Habitat suitability for striped hyena (area under different categories of suitability) in Gir National Park and Sanctuary, Gujarat, India.

Category	Area (km^2)	Percent area
Highly suitable	653.99	46.31
Suitable	454.66	32.20
Moderately suitable	206.51	14.62
Least suitable	096.96	06.87

Table 7.5: Different habitat types in Gir National Park and Sanctuary, Gujarat, India.

Habitat/Forest Type	Area in km^2	Percentage area
Riveraine Forest	367.15	9.92
Moist Mixed Forest	187.85	26.00
Tectona/Anogeissus-Acacia-Zizyphus	104.07	17.38
Acacia-Tectona/Anogeissus	1.38	25.22
Acacia-Lannea-Boswellia	245.47	7.37
Thorn Forest	356.09	13.30
Agriculture	10.03	0.10
Waterbody	140.09	0.71
Total	1412.13	100.00

Table 7.6: Different category of canopy cover or forest density in Gir National Park and Sanctuary, Gujarat, India.

Category	Area in km²	Percentage area
<10%	191.98	13.60
10 - 40%	705.54	49.96
40 - 70%	377.42	26.73
>70%	129.32	9.16
Waterbody	7.87	0.56
Total	1412.13	100.00

The results revealed that 46.31 percent (653.99 km²) of GNPS is highly suitable for striped hyena and 32.20 percent (454.66 km²) suitable, 14.62 percent (206.51 km²) moderately suitable, whereas 6.87 percent (96.96 km²) are least suitable (Table 7.4) (Fig. 7.16). GNPS is a well-managed protected area in India that has not given only significant result in terms of Asiatic lions (*Panthera leo persica*) conservation, but also supported the other big carnivores like leopard (*Panthera pardus*) and given umbrella protection to many threatened and rare species like striped hyena. The highly suitable habitat for striped hyena in GNPS comprises of around 46.31 percent is also depicts the success and well management of this protected area. The habitats which are highly suitable are distributed all over the study area and concentration is high in eastern part followed by western end of the park and less in national park area. This is probably due to favourable habitat condition that is low tree density and high grass cover in eastern part as compare to national park and western sanctuary as correlated the hyena population and habitat of GNPS (Alam et al., 2009).

Population estimate of striped hyena using photographic capture-recapture in GNPS also support the habitat suitability model as population density was found high in eastern part as compare to the national park and western part of the Gir National Park and Sanctuary (Alam et al., 2009). Other reason could be due to high density of natural predators- lions (13th Asiatic Lion Population Estimate, 2010) and leopards (M.S. Alam, unpublished data) in eastern part, compared to western part of the park, provide more kills for the natural scavengers like striped hyena. Striped hyenas are reported to be found near the human habitations (Prater, 1971; Kruuk, 1976; Hofer and Mills, 1998), where they occasionally feed on human food leftovers and carcass of livestock. In GNPS, majority of temporary settlements and villages are located in the eastern part and less in western part whereas there is no human settlement in the National Park area.

The analysis suggested that besides other factors, forest type- *Acacia-Tectona/Anogeissus*, forest density (10-40%), drainage, water points have played great role in governing the habitat suitability index. Habitat fragmentation is the most critical conservation concern particularly in regions with tropical forests, which are the greatest living repositories of biological diversity on earth. Enormous literature exists on the effects of habitat disturbing factors on plant and animal communities in the tropics (Saunders et al., 1991).

Further, the study revealed that GNPS supports diversified wildlife habitats (Table 7.5). The forest density of the area is fairly good for animals like striped hyena in GNPS. Approximately 9.16 percent of forest area is covered by crown density of more than 70%, while 26.73 percent with the density class of 40–70 percent, 49.96 percent with the density class of 10-40% and 13.60 percent with the density class of less than 10 percent (Table 7.6). Striped hyena preferred open forest and availability of 46.96 percent area as open forest support the striped hyena habitat suitability model while high forest density made the National Park area for the striped hyena moderately suitable compare to other parts. GNPS falls in semi-arid zone of Gujarat state in India, is one of the well protected forests, having open and thorn forests that provide favorable resources for the survival and protected undulating and safe denning refuge for the shelter for striped hyena. The availability of fair percentage of highly suitable habitat is encouraging and indicates GNPS can be serve as an important area for protecting striped hyena in India.

CONCLUSION

The striped hyena is a medium-sized carnivore species with overall appearance reminiscent of a dog. Muzzle pointed and head broad with long, pointed ears. Back slopes downward from the head to the tail. Coat has black vertical stripes on the side, horizontal stripes on the legs, and a distinctive dark patch or broad, dark "stripes" on the throat. Underfur coloration is light grey or light brown; however, some individuals may appear whiter or dirty whiter. Pelage coloration varies by region and may vary seasonally in the colder parts of its range (Pocock, 1934; Rosevear, 1974; Ilani, 1975). Ground colour of the pelt is typically grey to light brown, but may appear strikingly white even within the same population. Pups ground colour appears very white and the contrast between the ground colour and the black striation patterns is much more apparent (Rosevear, 1974; Riege, 1978; Wagner, 2006; Alam, this study). Longest hairs are up to 200 mm long (Rosevear, 1974) and fall along the mid-dorsal line. The black dorsal mane may be held erect, significantly increasing the apparent size of the animal (Pocock, 1934; Kruuk, 1976; Riege, 1978). Legs appear thin relative to their length and the hind legs are shorter than the forelegs. Feet have four toes with four short, non-retractable claws (Pocock, 1916). The tail is long with long coarse hairs. Striped hyenas have a well-developed anal pouch, a slit-like glandular orifice over-arching the anus from either side. The anal pouch may be inverted and thus be apparent while pasting or presenting during social encounters (Fox, 1971; Kruuk, 1976; Rieger, 1978). In juveniles, there is an unusual convergence in genital appearance

between sexes. Juvenile females have well defined labia-like folds anterior to the vagina. These ridges are hairless and darker than the surrounding tissue. Juvenile males have smaller, smooth, hairless pre-scrotal skin folds along the middle septum close to, but anterior to, the scrotum (Wagner, 2006). Unlike spotted hyenas, *Crocuta crocuta*, these genital characteristics are not enough to confuse the sexing of juveniles and adult genitalia appear normal. There is no apparent sexual dimorphism in body measurements and weight (Wagner, 2006). From the Kenya study, mean (95% CI) body measurements (cm or kg) were: head-body=108.3 (98-118, 55); tail=29.4 (26-36, 55); hind-foot=21.6 (19.4-24.5, 54); ear=14.7 (12.6-16, 51); weight=30.0 (23-35, 35). The skull differs from that of *Crocuta* in being slightly smaller in size and less massive in build (Rosevear, 1974). Permanent dentition is distinctly carnassial and the dental formula is i 3/3, c 1/1, p 4/3, m 1/1=34. Compared with *Crocuta*, the upper molar is much larger, as much as twice or more the size of the first premolar (Rosevear 1974; Coetzee, 1977).

Of the four extent species of hyena only Striped Hyena (*Hyaena hyaena*) occurs in India. The striped hyena has a very large range extending from Africa, north of and including the Sahel, and including much of East and North-east Africa, through the Middle East, Caucasus region, Central Asia, and the Indian subcontinent. Across their wide range, current distribution is patchy and most populations are likely composed of isolated small populations.

The current distribution of the species was reviewed extensively by Hofer and Mills (1998). In North Africa, their distribution extends from southern Morocco eastward along the extent of the North African coast to Egypt. They are absent from the central Sahara, their distribution in West Africa extending from Senegal in the drier Sahelian zone through Mauritania and Mali to Burkina Faso, Niger, northern Nigeria, southern Chad, and northern Cameroon. In East and North-east Africa, their range extends from Egypt south throughout much of the Horn to northern and central Tanzania. Although historically present, there are no reliable recent records of occurrence in Tunisia, Sudan, Eritrea, and Somalia (Hofer and Mills 1998).

The striped hyena historically widespread throughout most part of India except for regions of deciduous evergreen forest in the southwest. In southern India the distribution is peculiar. It is present in the dry prone area (<900mm rainfall) of the Deccan plateau but is not found in heavier dense forest (>1000mm rainfall), nor in evergreen and semi-evergreen forms of Western Ghats (1500-6000mm rainfall), (Hofer and Mills, 1998). It is present in the northern strip of the coastal plains in Karnataka and Goa state, up to western Ghats (4000 to 6000mm rainfall) where the original evergreen forms are now entirely replaced by cultivation. Once they were common all over the Karnataka, apparently becoming scarce everywhere (Karanth, 1982, 1986). In northern and eastern India it also continues to exist outside conservation areas and also near the human settlements. In many conservation areas throughout the subcontinent including Ranthambore, Kanha,

Palamau, Madhumalai, Bandipur, Anamallai, Jawahar and Corbett (Nair et al., 1977; Kothari et al., 1989), Gir National Park and Sanctuary (Singh et al., 1996; Saharia, 1998; Sinha, 2004; Alam, 2006; Alam, this study), Sariska (Saharia, 1998) and Kutch (Jhala, 2002), and reported at maximum altitude of 2,500m (Hofer, 1998).

The striped hyena generally favors open or thorn bush areas in arid to semi-arid environments (Prater, 1971; Rosevear, 1974; Kruuk, 1976; Rieger, 1978; Leakey et al., 1999; Wagner, 2006; Alam, this study), and avoid open desert and dense thickets and forests (Rosevear, 1974; Rieger, 1979a; Heptner and Sludskii, 1980), where water is available within 10 km (Rieger, 1979a), and favors large caves for resting (Kruuk, 1976; Rieger, 1979a; Leakey et al., 1999; Alam, this study). Rocky ridge are used for dening if area is hilly and undulating (Kruuk, 1976; Alam, this study).

The striped hyena occurs at low population densities throughout its distribution range. The only quantitative estimate of striped hyena density in Africa comes from the Serengeti National Park, based on observation of limited number of individuals, where density was estimated as greater than 0.02 striped hyena per km^2 (Kruuk, 1976), and from a study in Laikipia District, Central Kenya, estimated the minimum regional density at 0.03 adult striped hyena per km^2 (Wagner, 2006). While, a density of 0.065 adult striped hyena per km^2 was reported from Gir National Park and Sanctuary, Gujarat, India (Alam, this study).

For comparison, spotted hyena in the same ecosystem have been estimated to exceed 1 individual per km^2, and 0.02 per km^2, 0.03 per km^2 and 0.065 per km^2 is substantially lower than the densities of spotted hyenas, lions in most ecosystems (also in Gir National Park and Sanctuary, where lion density was estimated as 0.21 per km^2 (Gujarat Forest Department, 2010)), and even lower than the density of endangered African wild dogs (Creel and Creel, 1996).

The structure of hyenas fits for its particular mode of life, which is feed on prey killed by other animals (Prater, 1971). The striped hyena is classic scavenger, existing around human settlements and feeds on dried bones, carcasses and also on fruits, insects and reptiles (Kruuk, 1975; Kruuk, 1976; Hofer, 1998, Alam, this study). Striped hyenas have been reported to consume a wide variety of vertebrates, invertebrates, vegetables, fruit, and human originated organic wastes (Harrison, 1968; Ilani, 1975; Kruuk, 1976; Macdonald, 1978; Leakey et al., 1999; Wagner, 2006, Alam, this study).

The striped hyena is also known for occasional killing of livestock (Prater, 1971; Kruuk, 1976; Hofer, 1998). There are records of attacks by striped hyena on sheep, goat and donkey from North Africa, Israel, Iran, Pakistan and India, on horse in Iran and on dogs in India (Hofer, 1998). Overall, the evidence indicates striped hyenas in GNPS are solitary nocturnal foragers for which fruit and vegetable matter, where available, may play a significant part of the diet. Striped hyenas also regularly consume insects, invertebrates, small vertebrates, and

actively hunt small mammals and ground-nesting and/or ground-feeding birds. In addition, they scavenge off carcasses of larger mammals and this activity appears to account for a significant portion of the bones collected at den sites (kruuk, 1976; Wagner, 2006; Alam, this study).

Striped hyenas are considerably quieter than the spotted hyena (Rosevear, 1974) in terms of both volume and frequency of vocalizations, and are generally silent (Kruuk, 1976). However, vocalizations are similar to those of the spotted hyena and include *whining* by pups before suckling, *giggling* when frightened, *yelling* when being chased by conspecifics, *lowing* in a defensive position, *growling* when play or food-fighting, and a call by the mother to her pups (Kruuk, 1976; Rieger, 1981; Wagner, 2006; Alam, this study).

Striped hyena pups are reared in dens and intense digging behavior in the females announces parturition (Rieger, 1979a). Dens may be holes dug by the mother, holes formed and abandoned by other species (Prater, 1971; Alam, this study) or deep, natural, and sometimes complex, caves (Heptner and Sludskii, 1980; Kerbis-Peterhans et al. 1992; Leakey, et al., 1999; Alam, this study). Mothers carry food back to the den for their pups (Kruuk, 1976; Davidar, 1985; Davidar, 1990; Alam this study) and prepare meat for pups by biting off pieces (Rieger, 1979a).

The striped hyena considered subordinate to lions and spotted hyenas in African ecosystem, although Kruuk (1976) described a mutual attraction between the two Hyaenids. In GNPS also there was no direct competition was observed with the lions and leopard. Humans are consistently indicated as the major source of mortality throughout the evaluated range (Hofer, 1998). Although, striped hyena is an important member of the ecosystem. But due to some cultural and economical value and due to habitat loss and fragmentation the population is declining (Hofer and Mills, 1998) and facing extinction in several ranges (Kruuk, 1976). The striped hyena is considered as data deficient and threatened animal in several areas of its geographical range (Hofer and Mills, 1998).

IUCN - Near Threatened. CITES - not listed. Humans are consistently indicated as the major source of mortality throughout the evaluated range (Hofer, 1998) and were responsible for 50% of recorded deaths in central Kenya (Wagner, 2006). Negative perceptions of the species persist throughout its range and collection of human remains, grave robbing and incidents of damage to agriculture and livestock perpetuate negative attitudes. In North Africa, the brain of striped hyena is used as an aphrodisiac and hairs are used as talisman (Ronnefeld, 1969; Rieger, 1979a;). Poisoning at oases in Egypt has been cited as a cause of population declines in addition to hunting for utilization of the whiskers and eyeballs as protection from the evil eye and the heart for courage (Prater, 1971). In Ethiopia, the species is protected; however, hunting under a special permit is allowed (Hofer and Mills 1998). Habitat destruction is viewed as a threat in Kenya and

effective protection is absent as hyenas are viewed with contempt. In this region, due to the lack of differentiation between the species, striped hyenas are often killed when spotted hyenas are the intended target (Wagner, 2006). The Moroccan population has declined drastically and the remaining population has withdrawn into the southern mountainous regions (Hofer and Mills, 1998). In Niger, the population is declining as a result of officially sanctioned eradication or poisoning and by habitat destruction. The main source of recorded mortality in Tanzania is road kills.

In India habitat destruction is viewed as a threat and effective protection is absent as hyenas are viewed with contempt. In this region, due to the lack of differentiation between the species, striped hyenas are often killed when wolf and leopard is the intended target. The population has declined drastically and the remaining population has withdrawn into the small patches (Hofer and Mills, 1998). In Gujarat no proper record is available for the status of striped hyenas, the population is declining as a result of unofficially eradication or poisoning and by habitat destruction. The main source of recorded mortality in Gujarat and nearby GNPS is road kills. Around 13 death of striped hyena was recorded from in and around GNPS out of that one was natural (probably fight with the leopard), one was a poaching incident, 3 was poisoning case and 8 was due to the road accident.

Records also indicate that the species occurs outside of protected areas in number regions of its distribution range. Because they exist outside of formally protected

areas in regions where pastoralism is the norm and the potential for human-carnivore conflict is very high, populations in India are exceptionally vulnerable to human population growth, habitat destruction, poisoning and road accident. Particular attention should be paid to ensuring the survival of the species in pastoral areas by identifying ways to reduce human-carnivore conflict through promotion of methods that ensure adequate numbers of prey persist *and/or* methods that reduce livestock killing by carnivores and road accidents.

Other hyenas have extensively studied (Kruuk, 1972; Mills, 1978, 1984, 1989) compare to striped hyena (Kruuk, 1976; Wagner, 2006; Alam, 2006; Alam, this study), there are large gaps in our understanding of many aspects of their ecology. The population dynamic and mating systems in particular are imperfectly understood. Furthermore, their appear to be several options individual can choose, for example, 1) extent of home range, 2) dispersion and 3) males can be nomadic or belong to a group, and it is not known under which conditions these options are chosen. For this, long-term studies on known individuals are essential. Studies on more habitats would be valuable for learning the extent of behavioral flexibility of the species. Of the four members of Hyaenidae the striped hyena is the least known even though it has the widest distribution range (Kruuk, 1976; Rieger, 1979; Wagner, 2006; Alam, this study). Studies on this species are urgently needed, both to help in its conservation and to further investigate the effects of diet and food dispersion on behavior and social organization, role in ecological function and relation with the other carnivores.

The main findings of this study are:

- Striped hyenas are present in all over the Gir National Park and Sanctuary (GNPS).
- Mean density of striped hyena was estimated as 6.5 adult individual/100 km^2.
- Availability of favorable resources could be the factor for having this population. Although a quantitative density estimate is needed from an unprotected or degraded forest habitat of India of this species.
- Eastern Sanctuary has higher density of striped hyena (11.69 indvidual/100 km^2 while western sanctuary has lowest density 2.27 indivudual/100 km^2 and central part as 3.78 individual/100 km^2.
- The vegetation composition and density, shrub and grass cover for hide, availability of food, and safe denning sites could be the reasons for this variation of striped hyena population in different zones of GNPS.
- Striped hyena was found as extremely nocturnal with rare sighting in GNPS.
- Photographic capture-recapture sampling technique was found appropriate in GNPS for rare and nocturnal species with natural markings.
- Minimum number of hairs to be examined per scats was found as 21 hairs to detect all possible mammalian prey items with 95% confidence limit in striped hyena scats.
- Minimum number of scats to be analyzed was found as 40 scats for striped hyena of GNPS.

- Striped hyena was found as omnivorous that feed on variety of food items from big mammals (buffalo, bluebull, sambar) to small mammals (rodents) that is supplement by seasonal fruits.

- Chital and hare were found as most common mammalian species eaten by striped hyena in GNPS.

- *Zizyphus* spp. and *Diospyros melanoxylon* was found as most common fruits eaten by striped hyena in GNPS in their respective seasons, thus variation was found in the diet between winter and summer.

- Total mammalian biomass consumed by striped hyena was around 3668.58 kg, from 699 scats collected between April 2006 to July 2009.

- Both wild as well as domesticated prey contributes around equal biomass in the striped hyena diet in GNPS.

- The decline in domestic biomass contribution and increase in wild prey biomass contribution was observed from data 2006 to 2009 in striped hyena diet in GNPS.

- In western and eastern GNPS contribution of domestic biomass was found higher than wild prey biomass, while in central GNPS wild prey biomass contribution was higher than domestic biomass in the diet of striped hyena.

- Mixed forest was found as most utilized habitat type by hyena followed by *Tectona-Acacia-Zizyphus.*

- *Acacia-Lannea-Boswellia* vegetation type was utilized mainly for denning and resting by hyena in GNPS.

- There was no difference in the habitat use by striped hyena was observed between summer and winter in GNPS.

- Moist mixed forest type is least utilized and *Acacia-Lannea-Boswellia* more utilized by striped hyena in compare to lion and leopard.

- Tree density was found as negative correlated while grass cover was found as positive correlated with hyena population.

- Tree density was low in east zone compare to other three zones.

- Higher striped hyena density in eastern GNPS could be due to availability of suitable refuge in the form of ridges, high predator density and human habitation compare to western GNPS.

- Striped hyena was identified as solitary animal but they can found in communal denning system.

- Sandy dens are more preferred for denning as they can be constructed according to requirement, that provide more protection to pups from natural enemies.

- Total three type of structures utilized by striped hyena in GNPS for resting and pup rearing process.

- Newly born pups were only found in between January and March season suggesting that striped hyena gave birth to pups in winter season.

- The mean litter size was found 3 ± 0.44 SE, while minimum litter size was found as 2 and maximum was 4 pups in a single litter.

- Striped hyenas were found solitary in all the active time but clan (a group of hyena) can be observed at den site. Largest clan was recorded of 8 individual and smallest of 3 individuals in GNPS.

- Striped hyena was found as very calm animal produce any sound very occasionally.

- Habitat suitability for striped hyena in GNPS was analyzed using binomial multiple logistic regression.

- Approximately 9.16 percent of forest area is covered by crown density of more than 70%, while 26.73 percent with the density class of 40–70 percent, 49.96 percent with the density class of 10-40% and 13.60 percent with the density class of less than 10 percent.

- The analysis suggested that besides other factors, forest type- *Acacia-Tectona/Anogeissus*, forest density (10-40%), drainage, water points have played great role in governing the habitat suitability index.

- The results revealed that 46.31 percent (653.99 km^2) of GNPS is most suitable for striped hyena and 32.20 percent (454.66 km^2) suitable, 14.62 percent (206.51 km^2) moderately suitable, whereas 6.87 percent (96.96 km^2) are least suitable.

- The overall classification accuracy of 86.5 percent was observed which depict that model is only 13.5 present away from the ideal.

- The model performance assessed by the area under the ROC curve was found 0.902 implying that the present model is an effective model.

- Habitat suitability modelling accurately predicted striped hyena habitat with respect to density in GNPS. The model output can easily be interpreted by

experts and managers, having thereby a great practical importance and would serve as baseline for future management planning for the conservation of the species.

- Radio-telemetry study is needed to study breeding, social behavior, home range and their relation and interaction with the natural predators of GNPS.

- Studies on this species are urgently needed, both to help in its conservation and to further investigate the effects of diet and food dispersion on behavior and social organization.

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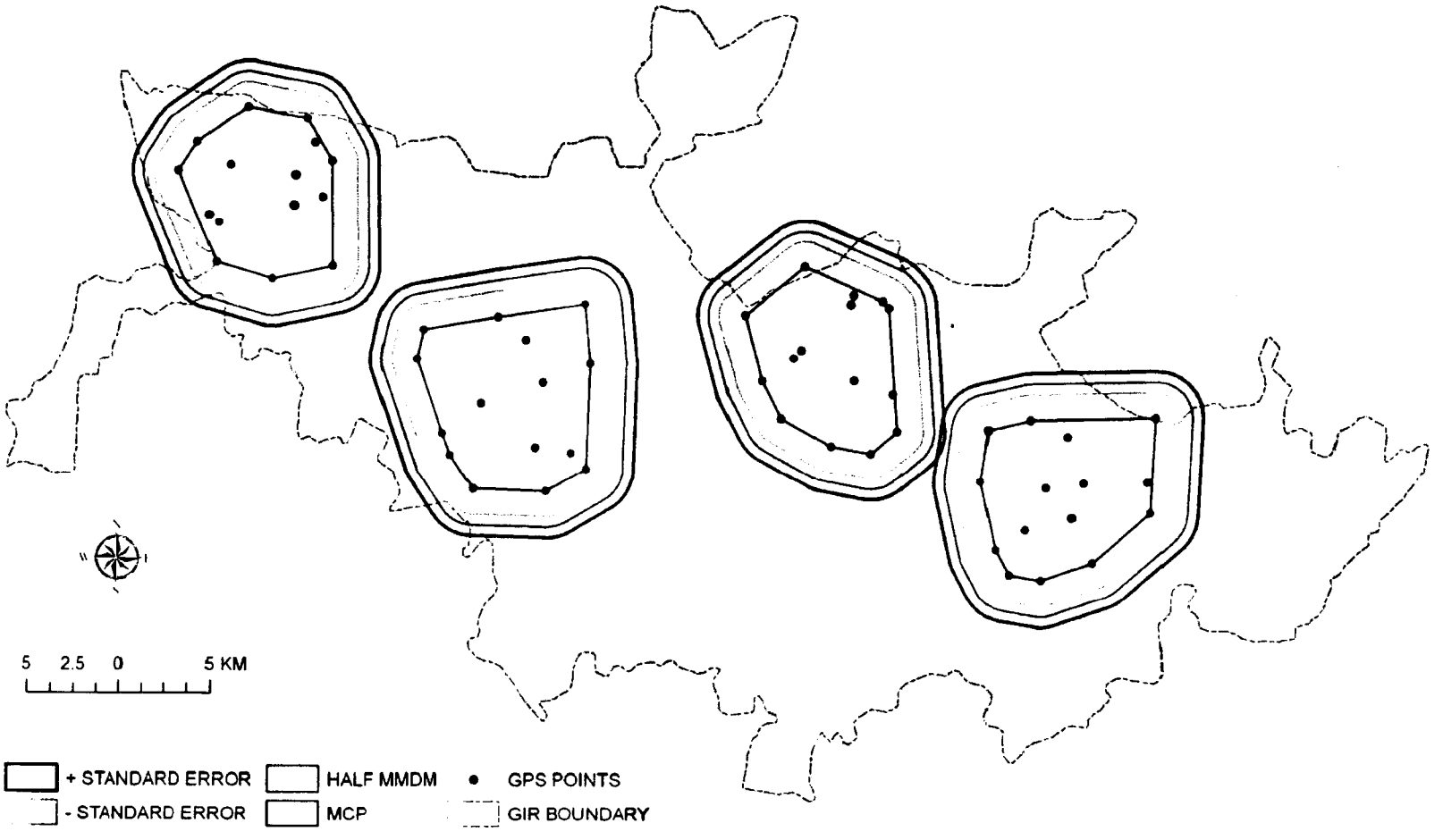
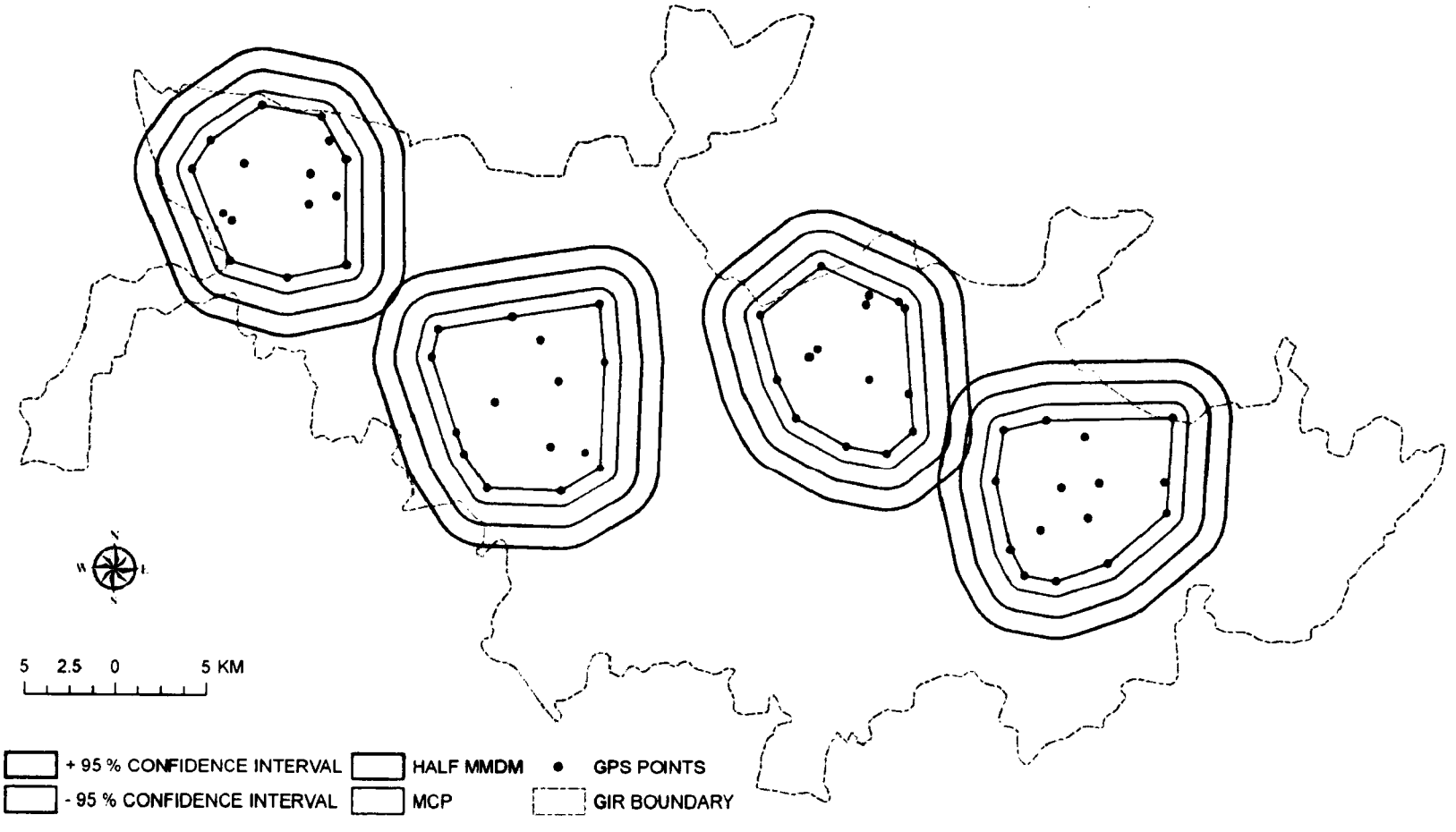
Appendix-I



Camera trap sampled area with ± standard error of HMMDM.



Camera trap sampled area with ± confidence interval of HMMDM.

Appendix-II

List of Mammals of Gir National Park and Sanctuary

S. No.	Order	Family	Common Name	Zoological Name	Local Name
1	Insectivorous	Soricidae	Grey Musk Shrew	*Sancus murinus (Linn.)*	Chachunder
2	Insectivorous	Erinaceidae	Pale hedgehog	*Paraechinus micropus (Blyth)*	Shero
3	Chiroptera	Pteropodidae	Flying Fox	*Pteropus giganteus (Brunnich)*	Shiyal
4	Chiroptera	Megadermatidae	Lesser False Vampire*	*Megaderma spasma (Linn)*	
5	Chiroptera	Pteropodidae	Short-Nosed Fruit Bat	*Cynopterus sphinx (Vahl)*	Chamachidiyu
6	Chiroptera	Vespertilionidae	Indian Pipistrelle	*Pipistrellus coromandra (Gray)*	
7	Chiroptera	Emballonuridae	Bearded Sheathtailed Bat	*Tophozous melanopogon (Temminek)*	
8	Primates	Cercopithecidae	Hanuman Langur	*Presbytis entellus (Dufreone)*	Hanuman langur
9	Pholidota	Manidae	Indian Pangolin	*Manis crassicaudata (Gray)*	Kidikhau
10	Lagomorpha	Leporidae	Indian Hare	*Lepus nigricollis (F.Cuvier)*	Sasloo
11	Rhodentia	Sciuridae	Five striped Palm Squirrel	*Funambulus pennanti (Wroughton)*	Panch tapka Khiskoli
12	Rhodentia	Cricetidae	Indian Gerbille	*Tetra indica (Hardwicke)*	Oonder
13	Rhodentia	Muridae	Field Mouse	*Mus booduga (Gray)*	Kshetriya oonder
14	Rhodentia	Muridae	Common House Rat	*Rattus rattus rattus (Linn.)*	Oonder
15	Rhodentia	Muridae	Kutch Rock Rat	*Rattus rattus girensis (Hington)*	Kutch oonder
16	Rhodentia	Muridae	Rock Rat	*Rattus rattus rufescens (Gray)*	Oonder
17	Rhodentia	Muridae	Bandicoot Rat	*Bandicota indica (Bechstein)*	
18	Rhodentia	Muridae	Indian Mole Rat	*Bandicota bengalensis (Gray & Hardwicke)*	
19	Rhodentia	Hystricidae	Indian Porcupine	*Hystrix indica (Kerr)*	Shahudi

20	Carnivora	Canidae	Jackal	*Canis aureus (Linn.)*	Shiyal
21	Carnivora	Canidae	Indian Fox	*Vulpes bengalensis (Shaw)*	Lonkdi
22	Carnivora	Mustelidae	Ratel or Honey Badger	*Mellivora capensis (Schreber)*	Ghorkhodiya
23	Carnivora	Viverridae	Small Indian Civet	*Viverricula indica (Desmarest)*	Vij
24	Carnivora	Herpestidae	Common Mongoose	*Herpestes edwadsi (Geoffroy)*	Noliyo
25	Carnivora	Herpestidae	Small Indian Mongoose	*Herpestes auropunctatus (Hodgson)*	Nano noliyo
26	Carnivora	Herpestidae	Ruddy Mongoose	*Herpestes smithi (Gray)*	Noliyo
27	Carnivora	Hyaenidae	Stripped Hyena	*Hyaena hyaena (Linn.)*	Jharakh
28	Carnivora	Felidae	Asiatic Lion	*Panthera leo persica (Meyer)*	Sinh/Savaj
29	Carnivora	Felidae	Leopard/Panther	*Panthera pardus (Linn.)*	Dipdo
30	Carnivora	Felidae	Jungle Cat	*Felis chaus (Giildenstaedt)*	Jungli biladi
31	Carnivora	Felidae	Desert Cat	*Felis libyca (Foster)*	Rann biladi
32	Carnivora	Felidae	Rusty Spotted Cat	*Felis rubiginosa (Geoffrey)*	Tramra vaarni Tapkavali biladi
33	Artiodactyla	Suidae	Indian Wild Boar	*Sus scrofa (Linn.)*	Jangli bhund
34	Artiodactyla	Cervidae	Sambar	*Cervus unicolor (Kerr)*	Sambar
35	Artiodactyla	Cervidae	Chital/Spotted Deer	*Axis axis (Erxleben)*	Chital
36	Artiodactyla	Bovidae	Chinkara/Indian Gazelle	*Gazella gazella (Pallas)*	Chinkara
37	Artiodactyla	Bovidae	Blackbuck/Indian Antelope	*Antilope cervicapra (Linn.)*	Kaliyar
38	Artiodactyla	Bovidae	Chowsingha/Fourhorned Antilope	*Tetracerus quadricornis (Blainville)*	Chowsinga
39	Artiodactyla	Bovidae	Nilgai/Blue Bull	*Baselaphus tragocamelus (Pallas)*	Rose/Nilgai

* Recently recorded (M.S. Alam 2010. First record of False Vampire Bat *Megaderma spasma* Linnaues, 1758, in Gir National Park and Sanctuary. J. Bombay Nat. Hist. Soc., 107:2).

List of birds of Gir National Park and Sanctuary

S. No.	Common Name	Zoological Name
	Accipitridae	
1	Besra Sparrow Hawk	*Accipiter virgatus besra*
2	Black Winged Kite	*Elanus caeruleus*
3	Bonill's Eagle	*Hieraaetus fasciatus*
4	Booted Hawk Eagle	*Hieraaetus indus*
5	Brahminy Kite	*Haliastur*
6	Buzzard	*Buteo buteo vulpinus*
7	Crested Hawk Eagle	*Spizaetus cirrhatus*
8	Crested Serpanteagle	*Spilornis cheela cheela*
9	Egyptian Vulture	*Neophron percnopterus*
10	Griffon Vulture	*Gyps fulvus*
11	Goshawk	*Accipiter gentilis*
12	Honey Buzzard	*Pernis ptilorhyncus*
13	Imperial Eagle	*Aquila heliaca*
14	Indian Sparrow Hawk	*Accipiter nisus*
15	Indian Longbilled Vulture	*Gyps indicus*
16	Indian Whitebacked Vulture	*Gyps bengalensis*
17	King Vulture	*Sarcogyps calvus*
18	Longlegged Buzzard	*Buteo rufinus*
19	Marsh Harrier	*Circus aeruginosus*
20	Montagu's harrier	*Circus pygargus*
21	Osprey	*Pandion haliaetus*
22	Common Pariah Kite	*Milvus migrans*
23	Pallas's Fishing Eagle	*Haliaeetus leucoryphus*
24	Pale Harrier	*Circus macrourus*
25	Shikra	*Accipiter badius*
26	Short Toed Eagle	*Circaetus galliccus*
27	Tawny Eagle	*Aquila rapa vindhiana*
28	Black Eagle	*Ictinaetus malayensis*
29	White Eyed Buzzard Eagle	*Butastur tessa*
	Alcedinidae	
30	Black Capped Kingfisher	*Halcyon pileata*
31	Common Kingfisher	*Alcedo atthis*
32	Lesser Piedkingfisher	*Ceryle rudis*
33	White Breasted Kingfisher	*Halcyon smyrnensis*
	Alaudidae	
34	Ashycronwed Finch Lark	*Eremopterix grisea*
35	Singing Bush Lark	*Mirafra javanica*

36	Crested Lark	*Galerida cristata*
37	Redwinged Bushlark	*Mirafra erythroptera*
38	Rufous Tailed Finch	*Ammomanes phoenicurus*
39	Short Toed Lark	*Calandrella cinerea*
	Anatidae	
40	Common Pochard	*Aythya ferina*
41	Comb Duck	*Sarkidiornis melanotos*
42	Common Teal	*Anas crecca crecca*
43	Cotton Teal	*Nettapus coromandelianus*
44	Garganej	*Anas querquedula*
45	Lesser whistlingteal	*Dendrocygna javanica*
46	Mallard	*Anas platyrhynchos*
47	Pintail	*Anas acuta*
48	Redcrested Pochard	*Netta rufina*
49	Ruddy Brahmany duck	*Tadorna ferruginea*
50	Shoveler	*Anas clypeata*
51	Spotbilled Duck	*Anas poecilorhyncha*
52	Wigeon	*Anas penelope*
	Apodidae	
53	Alpine Swift	*Apus melba*
54	Crested Tree Swift	*Hemiprocne longipennis*
55	House Swift	*Apus affinis*
56	Palm Swift	*Cypsiurus parvus*
	Ardeidae	
57	Cattel Egret	*Bubulcus ibis*
58	Grey Heron	*Ardea cinerrea*
59	Indian Reef Heron	*Egretta gularis*
60	Large Egret	*Ardea alba*
61	Little Green Heron	*Ardeola striatus*
62	Little Egret	*Egretta garzetta*
63	Night Heron	*Nycticorax nycticorax*
64	Pond Heron	*Ardeola grayii*
65	Purple Heron	*Ardea purpurea*
66	Smaller or Median Egret	*Egretta intermedia*
	Burhinidae	
67	Great Stone Curlew/Plover	*Esacus magnirostries*
68	Stone Curlew	*Burhinus oedicnemus*
	Caprimulgidae	
69	Common Nightjar	*Caprimulgus asiaticus*
70	Franklin's Nightjar	*Caprimulgus affinis*
71	Indian Nightjar	*Caprimulgus indicus*

Capitonidae		
72	Crimson Breastedbarbet	*Megalaima haemacephala*
Campephagidae		
73	Black Headed Cuckoo Shrike	*Coracina melanoptera*
74	Common Wood Shrike	*Tephroornis pondicerianus*
75	Large Cuckoo Shrike	*Coracina novaehollandiae*
76	Small Minivet	*Pericrocotus cinnamomeus*
77	Whitebellied Minivet	*Pericrocotus erythropygius*
Ciconiidae		
78	Blacknacked Stork	*Ephippiorynchus asiaticus*
79	Openbill Stork	*Anastomus oscitans*
80	Painted Stork	*Mycteria leucocephala*
81	White Stork	*Ciconia ciconia*
82	Black Stork	*Ciconia nigra*
83	Whitenecked Stork	*Ciconia episcopas*
Charandrriidae		
84	Bartailed Godwit	*Limosa lapponica*
85	Black Tailed Godwit	*Limosa limosa*
86	Common Sandpiper	*Tringa hypoleucs*
87	Green Sandpiper	*Tringa ochropu*
88	Terek Sandpiper	*Tringa terek*
89	Green Shank	*Tringa nebularia*
90	Little Ringedplover	*Charadrius dubius*
91	Little Stint	*Calidris minutus*
92	Marsh Sandpiper	*Tringa stagnatilis*
93	Red-Wattled Lapwing	*Vanellus indicus*
94	Redshank	*Tringa totanus*
95	Ringed Plover	*Charadrius hiaticula*
96	Ruff and Reeve	*Philomachus pugnax*
97	Spotted or Dusky Redshank	*Tringa erythropus*
98	Whimbrel	*Numenius phaeopus*
99	Yellow-Wattled	*Vanellus malabaricus*
Columbidae		
100	Blue Rock Pegion	*Columba livia*
101	Green Pegion	*Treron phoenicoptera*
102	Indian Ring Dove	*Streptopelia decaocta*
103	Little Brown Dove	*Streptopelia senegalensis*
104	Red Turtle Dove	*Streptopelia tranquebarica*
105	Rufous Turtle Dove	*Streptopelia orientalis*
106	Spotted Dove	*Streptopelia chinensis*
Coraclidae		

107	Indian Roller	*Coracias benghalensis*
108	Kashmir Roller	*Coracias garrulas*
	Corvidae	
109	House Crow	*Corvus splendous*
110	Indina Tree Pie	*Dendrocitta vagabunda*
111	Jungle Crow	*Cvorvus macrorhyncho*
	Curulidae	
112	Common Hawk Cuckoo	*Cuculus varius*
113	Crow Pheasant	*Centrpus sinensis*
114	Cuckoo	*Cuculus canorus*
115	Koel	*Eudynamys scolopacea*
116	Pied Crested Cuckoo	*Clamator jacobinus*
117	Sirkeer Cuckoo	*Taccoua leschenaulti*
	Dicacidae	
118	Thickbilled Flower Pecker	*Dicaeum agile*
119	Tickell's Flower Pecker	*Dicaeum erythrorychos*
	Dicruridae	
120	Black Drongo	*Dicrurus adsimilis*
121	Grey Drongo	*Dicrurus leucophaeus*
122	White Bellied Drongo	*Dicrurus caerulenscens*
	Falconidae	
123	Hobby	*Falco subbuteo subbuteo*
124	Kestrel	*Falco tinnunculus*
125	Laggar Falcon	*Falco biarmicus jugger*
126	Peregrine Falcon	*Falco peregrinus japonensis*
127	Redheaded Merlin	*Falco chichquera*
128	Saker/Chirag Falcon	*Falco biarmicus cherrug*
129	Shahien Falcon	*Falco peregrinus peregrinator*
	Fringillidae	
130	Common Rose finch	*Carodacus erythrinus*
	Glarecolidae	
131	Indian Courser	*Cursorius coromandelicus*
132	Collared Swallow Plover	*Glareola lactea*
	Gruidae	
133	Common Crane	*Grus grus*
134	Demoiselle Crane	*Anthropoides virgo*
135	Sarus Crane	*Grus antigon*
136	Collared Sand Martin	*Riparia ripara*
137	Crag Martin	*Hirundo ruestris*
138	Dusky Crag Martin	*Hirundo concolor*

139	Indian Cliff Swallow	*Hirundo fluvicola*
140	Redrumped/Striated Swallow	*Hirundo daurica erythropygia*
141	Common Swallow	*Hirundo rustica*
142	Wiretailed Swallow	*Hirundo smithii*
	Irenidae	
143	Common Iora	*Aegithina tiphia*
144	Marshall's Iora	*Aegithina nigrolutea*
	Jacanidae	
145	Pheasant Tailedjacana	*Hydrophasianus chirurgus*
	Laridae	
146	Blackheaded Gull	*Larus ridibundus*
147	Brownheaded Gull	*Larus brunnicephalus*
148	Indian River Tern	*Sterna aurantia*
149	Little Tern	*Sterna albifrons*
150	Whiskered Tern	*Chlidonias hybrida*
	Laniidae	
151	Baybacked Shrike	*Lanius vittatus*
152	Grey Shrike	*Lanius excubitor*
153	Red Backed Shrike	*Lanius cllurio*
154	Rufousbacked Shrike	*Lanius schach*
	Meropidae	
155	Bluecheeked Bee Eater	*Merops superciliosus*
156	Green Bee Eater	*Merops orientalis*
	Muscicapidae	
157	Common Babbler	*Turdoides caudatus*
158	Jungle Babbler	*Turdoides striatus*
159	Large Grey Babbler	*Turdoidus malcolmi*
160	Rufousbellied Babbler	*Dumetia hyperythra*
161	Scimitar Babbler	*Pomatorhinus erythrogenys*
162	Yellow Eyed Babbler	*Chrysomma sinense*
	Motacillidae	
163	Brownpipit	*Anthus similis*
164	Forest Wagtail	*Motacilla indica*
165	Grey Wagtail	*Motacilla cinerea*
166	Indian Tree Pipit	*Anthus hodgsoni*
167	Large Pied Wagtail	*Motacilla maderaspatensis*
168	Paddy Field Pipit	*Anthus novaeseeladiae*
169	Towny Pipit	*Anthus campestris*
170	White Wagtail	*Motacilla alba dukhuensis*
171	Yellow Wagtail	*Motacilla flava*

172	Yellowheaded Wagtail	*Motacilla citreola*
	Nectariniidae	
173	Purple sunbird	*Nectarinia asiatica*
	Oriolidae	
174	Black Headed oriole	*Oriolus xanthornus*
175	Golden Oriole	*Oriolus oriolus*
	Otididae	
176	Lesser Florican	*Sypheotides indica*
	Paridae	
177	Grey Tit	*Parus major*
	Pelecanidae	
178	Dalmatian Pelican	*Pelecanus philippensis*
179	Rosy or White Pelican	*Pelecanus onocrotalus*
	Phalacrocoracidae	
180	Cormorant	*Phalacrocorax carbo*
181	Darter	*Anhinga rufa*
182	Indian Shag	*Phalacrocorax fuscicollis*
183	Little Cormorant	*Phalacrocorax niger*
	Phasianidae	
184	Grey Partridge	*Francolinus pondicerianus*
185	Grey Quail	*Coturnix coturnix*
186	Indian Peafowl	*Pavo cristatus*
187	Jungle Bush Quail	*Francolinus pictus*
188	Painted Partridge	*Francolinus*
189	Rain Quail	*Coturnix coromandelica*
190	Rock Bush Quail	*Perdicula argoondah*
	Phoenicopteridae	
191	Flamingo	*Phoenicopterus roseus*
192	Lesser Flamingo	*Phoeniconaias minor*
	Picidae	
183	Golden backed Woodpecker	*Dinopium benghalense*
194	Grey Woodpecker	*Picoides cjerdons*
195	Maharatta Woodpecker	*Picoides maharattensis*
196	Pigmy Woodpecker	*Picoides canicapillus*
197	Wryneck	*Jynx torquilla*
	Pittidae	
198	Indian Pitta	*Pitta bachyura*
	Ploceidae	
199	House Sparrow	*Passer domesticus*
200	Yelow Throated Sparrow	*Petronia santhocollis*
	Podicipedidae	

201	Little Grebe	*Tachydaptus ruficollis*
	Psittacidae	
202	Blossom Headed Parakeet	*Psittacula cyaocephala*
203	Roseringed Parakeet	*Psittacula krameri*
	Pteroclididae	
204	Indian Sandgrouse	*Pterocles exustus*
205	Painted Sandgrouse	*Pterocles indicus indicus*
	Pycnootidae	
206	Revented bulbul	*Pycnonots cafer*
	Rallidae	
207	Brown Crake	*Amoarornis akool*
208	Coot	*Fulica atra*
209	Eastern baillon's crake	*Porzana pusilla*
210	Moorhen	*Gallinula chloropus*
211	Purple Moorhen	*Porphyrio porphyrio*
212	Water Cock	*Gallicrex cinerea*
213	White breasted waterhen	*Amaurornis Phoenicurus*
	Recurvirostridae	
214	Avocet	*Recurvirostra avosetta*
215	Blackwinged stilt	*Himantopus himantopus*
	Rmberizidae	
216	Black headed bunting	*Emberiza melanocephala*
217	Crested bunting	*Emberiza lathami*
218	Greynecked bunting	*Emberiza buchanani*
219	Redheaded bunting	*Emberiza bruniceps*
220	Striolated bunting	*Emberiza striolata*
	Rostratulidae	
221	Fantail Snipe	*Gallinago gallinago*
222	Jack Snipe	*Capella minina*
	Stigidae	
223	Barn Owl	*Tyto alba*
224	Brown Fish Owl	*Bubo zeylonensis*
225	Brown Wood Owl	*Strix leptogrammica*
226	Collared scops Owl	*Otus bakhamoena*
227	Great Horned Owl	*Bubo bubo*
228	Mottled Wood Owl	*Strix ocellata*
229	Shorteared Owl	*Asio flammeus*
230	Spotted Owlet	*Athene brama*
	Sturnidae	
231	Bank Myna	*Acridotheres ginginianus*
232	Brahmin Myna	*Strnuspagodarum*

233	Common Myna	*Acridotheres trrstis*
234	Grey Hedded Mayna	*Sturnus malabaricus*
235	Rosy Pastor	*Sturnus roseus*
236	Blacknecked Flycatcher	*Hypothymis azurea*
237	Brown Flycatcher	*Musicacapa latirostris*
238	Grey Headed Flycatcher	*Culicicapa ceylonensis*
239	Paradise Flycatcher	*Terpsiphone paradisi*
240	Redbreasted Flycatcher	*Musicapa parva*
241	Rufoustailed Flycatcher	*Muscicapa ruficauda*
242	Spotted Flycatcher	*Musicapa striata*
243	Tickell's Blue	*Musicapa tickelliae*
244	Verditer Flycatcher	*Musicapa thalassina*
245	Whitebrowed Flycatcher	*Rhipidura aureola*
246	Whitespotted Flycatcher	*Rhipidura alboglari*
247	Ashy Wren Warbler	*Prinia socialis*
248	Blyth's Reed Warbler	*Acrocephalus dumetorum*
249	Booted Warbler	*Hippolais caligata*
250	Brown Leafwarbler	*Phylloscopus collybita*
251	Dull Green Leafwarbler	*Phylloscopus trochiloides*
252	Franklin's Wren Wrabler	*Prinia hodgsonii*
253	Grasshopper Warbler	*locustella naevia/certhiola*
254	Indian Great Reed Warbler	*Acrocephalus stentoreus*
255	Jungle Wren Warbler	*Prinia sylvatica*
256	Large Crowned Leafwabler	*Phylloscopus occipitalis*
257	Lesser Whitethroat	*Sylvia curruca blythi*
258	Moustached Sedge Warbler	*Acrocephalus melanoogon*
259	Olivaceous Leaf Warbler	*Phylloscopus griseolus*
260	Orphean Warbler	*Syivia hortensis*
261	Paddyfied Warbler	*Acrocephalus agricola*
262	Plain Wren Warbler	*Prinia subflavia*
263	Rufous Fronted Wren Warbler	*Prinia buchanani*
264	Streaed Fantail Warbler	*Cisticola juncidis*
265	Tailor Bird	*Orthotomus sutorius*
266	Tickell's Leaf Warbler	*Phylloscopus affinis*
267	White Throat	*Sylvia communis*
268	Black Bird	*Turdus merula*
269	Black Redstart	*Phoenicurus ochruros*
270	Blue Chat	*Erithacus brunneus*
271	Blue Throat	*Erithacus svecicus*
272	Blue Rock Thrush	*Monticola solitarius*
273	Blueheaded Rockthrush	*Monticola cinclorhynchus*

274	Indian Robin	*Saxicoloides fulcata*
275	Magpie Robin	*Copsychus saularis*
276	Pied Chat	*Oenanthe picata*
277	Pied Bush Chat	*Saxicola caprata*
278	Redstart	*Phoenicurus phoenicurus*
279	Stone Chat	*Saxicola torqueta*
280	Malabar whistling thrush	*Myiophonus horsfieldii*
281	Indian Baya	*Ploceus philippinus*
282	Red Munia	*Estrilda amandava*
283	Spotted Munia	*Lonchura punctulata*
284	Black Headded Munia	*Lonchura malacca*
285	Spotted Munia	*Lonchura punctulata*
286	White Throated Munia	*Lonchura malabarica*
287	Glossy Ibis	*Plegadis falcinellus*
288	Indian Black Ibis	*Pscudibis papillosa*
289	Spoonbill	*Platalea leucorodia*
290	White Ibis	*Threskiornis aethiopicus*
291	Common Bustard Quail	*Tunrix suscitator*
292	Little Bustard Quail	*Turnix sylvatica*
293	Yellow Legged Button Quail	*Turnix tanki*
294	Hoopoe	*Upupa epops*
295	White Eye	*Zosterops palebrosa*